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 in 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	Seminar	0+1
FSC 599	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 distribution or 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 of root 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 climatic conditions 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, New Delhi.
- 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 physiological role 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 Environmental Physiology 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 nutrition in 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 been formulated.

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	Seminar-I	0+1
FSC 692	Seminar-II	0+1
FSC 699	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 enhancing breeding efficiency.

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 advances in 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, New Delhi.
- 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 apply these 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 management practices 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 mitigate adverse 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 fruit and 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, 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 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, bioreactors for 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 realising smart 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	3+0
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	1+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	1+1
VSC 514	Postharvest Management of Vegetable Crops	2+1
VSC 591	Seminar	0+1
VSC 599	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 cultivated in 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 production economics 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 of cool 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.
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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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- 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.
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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 soil and 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 of warm 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, Chattopadhyay A, Karmakar K and Dutta S. 2011. *Modern technology for vegetable production*, New India publishing agency, New Delhi, 413p
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- Saini GS. 2001. *A text book of oleri and flori culture*. Aman publishing house.
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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 crop growth 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 and abscissic 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 fruit drops 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* (2^{nd} 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. Box 722200, Houston, Texas 77072, USA, 678p.
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- 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 chromosomes to 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 integral part 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; Breeding for 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 crop improvement.

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 of vegetable crops

- Understand how the basic principles are important to start breeding of vegetable crops

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.
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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. The students 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 mentioned crops;
- Molecular marker techniques to identify useful traits in the vegetable crops and special 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 of vegetable 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 hybrid technology 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, 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 crops vegetable 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, PPV and 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 biotic and 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 special breeding 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 cross pollinated 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.
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- 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.
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- 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 : 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 crop in 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 in tunnels, 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 and installation 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 vegetable crops; 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 in India
- 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 as entrepreneur

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 and development*.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 deterioration if proper checks are made at 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 processing before 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 quality maintenance IV. Seed harvesting, extraction and its processing V. Improved agro-techniques and field and seed standards

VI. Theory

Unit I

Introduction, history, propagation and reproduction—Introduction, definition of 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 technique and 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 important vegetables;
- 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 and post-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*. South asian Publ.

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- Basra AS. 2000. *Hybrid seed production in vegetables*. CRC press, Florida, USA.
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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.
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- Kalloo G, Jain SK, Vari AK and Srivastava U. 2006. *Seed: A global perspective*. Associated publishing company, New Delhi.
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- Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. Agro botanical publ.
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- 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 underutilized vegetable crops.

V. Aim of the course

To impart knowledge about production technology of lesser utilized vegetable crops The course is constructed given as under:

No.	Block	Unit
1.	Production of underutilized crops vegetable 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 crops in India
- Acquire knowledge about the production technology of underutilized

vegetable crops

- 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, populations and 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 vegetable crops

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 maintenance of 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.
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- 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 vegetable crops;
- 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 Publl. 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, which are 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 commonly used 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 science need 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 research institute, 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 plantation crops*. 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 vegetable crops

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 and quality 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 biochemistry III 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; Biochemistry of 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 to understand:

- 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 Crops	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	Seminar I	0+1
VSC 692	Seminar II	0+1
VSC 699	Research	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 and drumstick. 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 vegetable crops

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 and IBH.
- 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*. 2nd edn, 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 book distributing 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*. International book 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 okra crops 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 hybrid technology 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, we should mitigate abiotic stresses and adapt to the warming planet. The student of 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 stress management 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 high stress 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 crops production and their management practices.

Unit IV

Techniques of vegetable growing under water deficit, water logging, salinity and sodicity.

Unit V

Use of chemicals—techniques of vegetable growing under high and low temperature conditions, use of wild species, chemicals and antitranspirants in alleviation of different stresses.

VIII. Practical

- Identification of susceptibility and tolerance symptoms to various types of stress in 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*. Research periodicals 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 good quality 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 production and procurement 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, packaging and 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 marketing of 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. *Testing of 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 consumption of 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 continuing in 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 hybrid technology in Asia-Pacific Region*. FAO.
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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 of accessions;
- 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. Given the 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 culture laboratories (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 and plantation 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 and applied 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 analysis methods 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, phase contrast, 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	Seminar	0+1
FLS 599	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 techniques in 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 mechanisms in 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. Revised edition, 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: Traditional and 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 and marketing	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 specific guidelines 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 flower crops.
- 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 and marketing	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, Crop Insurance.

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 specific guidelines 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 loose flowers.
- 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 and informal 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 native plants), 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 landscape principles (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 thorough understanding of principles of landscape gardening
- Develop skills for landscaping under different situations and layout of garden components.

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 cultivation including 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 sexual propagation 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, budding and 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 flower crops.
- 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, New Delhi, India.
- Bose TK, Mitra SK and Sadhu M K. 1991. *Propagation of Tropical and Subtropical Horticultural Crops*. Naya Prokash, Kolkata, India.
- Chadha KL, Ravindran PL and Leela Sahijram. 2000. *Biotechnology in Horticulture and Plantation 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 management including 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 architecture and landscaping, Exposure to CAD (Computer Aided Designing) – Applications of CAD in landscape garden designing, 2D drawing by AUTOCAD, Creating legends for 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, making sample 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, Navigation Tools, 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, Exporting Images, 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 and designing.
- Develop the adequate skills to create 3 D model to showcase interaction of different factors in landscape gardening.
- Develop the entrepreneurial acumen

Suggested Reading

- Christine, Wein-Ping Yu. 1987. *Computer-aided Design: Application to Conceptual Thinking in 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 and methods of seed production in flower crops.
- Students will get awareness on seed standards, certification and law in flower crops.

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 Distributing Co., 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	Seminar-I	0+1
FLS 692	Seminar-II	0+1
FLS 699	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 and inhibition, 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, transpiration in 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 chain in 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 for enhanced 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, respiration rate, 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 electrolyte leakage (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 senescence in flower crops.
- The students would acquire the required skill sets of managing the storage and packaging 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 and foliage (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, fillers their 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 the growth 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 – Meristem culture 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 and cybrids, *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, approaches to 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 culture laboratories (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 and Gene 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 tool for 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 in mitigating 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 and diversity; 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 of flower 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

PLANTATION, SPICES, MEDICINAL AND AROMATIC CROPS

Course Title with Credit Load for M.Sc. (Hort.) in Plantation, Spices, Medicinal andAromatic Crops

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
PSM 501*	Production of Plantation Crops	2+1
PSM 502*	Production of Spice Crops	2+1
PSM 503*	Production of Medicinal and Aromatic Crops	2+1
PSM 504*	Breeding of Plantation and Spice Crops	2+1
PSM 505*	Breeding of Medicinal and Aromatic Crops	1+1
PSM 506	Systematics of Plantation and Spice Crops	1+1
PSM 507	Systematics of Medicinal and Aromatic Crops	1+1
PSM 508	Underexploited Plantation, Spice, Medicinal and Aromatic Crops	2+0
PSM 509	Growth and Development of Plantation, Spice, Medicinal and Aromatic Crops	2+1
PSM 510	Biochemistry of Plantation, Spice, Medicinal and Aromatic Crops	2+1
PSM 511	Biodiversity and Conservation of Plantation, Spice, Medicinal and Aromatic Crops	2+1
	Minor Courses	08
	Supporting Courses	06
	Common compulsory courses	05
PSM 591	Seminar	0+1
PSM 599	Research	0+30
	Total	**70**

*Compulsory among major courses

I. **Course Title** : **Production of Plantation Crops**

II. **Course Code** : **PSM 501**

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

IV. **Why this course ?**

Plantation crops play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers. This course will impart theoretical as well as hands-on experience to the learner on scientific production technology of various plantation crops in Indian perspectives. It will provide comprehensive knowledge in this regard.

V. **Aim of the course**

The course is designed to provide both basic and applied knowledge on various aspects of production technology of plantation crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Plantation Crops	I Role of plantation crops II Export potential III Promotional programmes
2	Production Technology	I Varietal wealth II Propagation and nursery management III Agro techniques
3	Harvest and Post-harvest	I Maturity indices and harvest management II Post harvest management

VI. **Theory**

Block 1: **Importance of Plantation Crops**

Unit 1: Role of plantation crops: Role of plantation crops in national economy, area-production statistics at national and international level, classification, clean development mechanism and carbon sequestration potential of plantation crops.

Unit 2: Export potential: Export potential, problems and prospects and IPR issues in plantation crops.

Unit 3: Promotional programmes: Role of commodity boards and directorates in the development programmes of plantation crops.

Block 2: **Production Technology**

Unit 1: Varietal wealth: Botany, taxonomy, species, cultivars and improvedvarieties in plantation crops.

Unit 2: Propagation and nursery management: Plant multiplication including *in-vitro* multiplication, nursery techniques and nursery management in plantation crops.

Unit 3: Agro techniques: Systems of cultivation, cropping systems, multitier cropping, climate and soil requirements, systems of planting, high density planting, nutritional requirements, water requirements, fertigation, moisture conservation, role of growth regulators, macro and micro nutrients, nutrient deficiency symptoms, physiological disorders, shade regulation, weed management, training and pruning, crop regulation, plant protection, management of drought, precision farming, organic production practices.

Block 3: **Harvest and Post harvest management**

Unit 1: Maturity indices and harvest: Maturity indices, harvesting methods, harvesting seasons and mechanized harvesting in plantation crops.

Unit 2: Post harvest management: Post harvest handling including primary processing, grading, packaging, storage and benefit cost analysis of plantation crops.

Crops

Coconut, Arecanut, Oilpalm, Cashew, Coffee, Tea, Cocoa, Rubber, Palmyrah, Betel vine

VII. Practical

- Description of botanical and varietal features;
- Selection of mother palms and seedlings;
- Nursery techniques;
- Soil and water conservation measures;
- Nutrient deficiency symptoms;
- Manuring practices;
- Pruning and training methods;
- Maturity standards;
- Harvesting;
- Project preparation for establishing plantations;
- GAP in plantation crops;
- Exposure visits to commercial plantations, research institutes.

VIII. **Teaching Methods/ Activities**

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. **Learning outcome**

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

- Develop the technical skill in commercial cultivation of plantation crops
- Be able to start plantation crop-based enterprises

X. **Suggested Reading**

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press. Anonymous. 1985. *Rubber and its Cultivation*. The Rubber Board of India.
- Chopra VL and Peter KV. 2005. *Handbook of Industrial Crops*. Panima.
- Choudappa P, Anitha K, Rajesh MK and Ramesh SV. 2017. *Biotechnology of Plantation Crops*.Daya Publishing House, New Delhi
- Choudappa P, Niral V, Jerard BA and Samsudeen K. 2017. *Coconut*. Daya Publishing House, New Delhi.
- *e-manual* on Advances in Cashew Production Technology. ICAR – Directorate of Cashew Research, Puttur –574 202, DK, Karnataka.
- Harler CR. 1963. *The Culture and Marketing of Tea*. Oxford Univ. Press.
- Joshi P. 2018. *Text Book on fruit and plantation crops*. Narendra Publishing House, New Delhi Kurian A and Peter KV. 2007. *Commercial Crops Technology*. New India Publ. Agency.
- Nair MK, Bhaskara Rao EVV, Nambia KKN and Nambiar MC. 1979. *Cashew*. CPCRI, Kasaragod.
- Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.
- Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.
- Peter KV. 2002. *Plantation Crops.* National Book Trust.
- Pillay PNR. 1980. *Handbook of natural rbber production in India*. Rubber Research Institute, Kottayam. pp.668.
- Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2007. *Management of Horticultural Crops.* Parts I, II. New India Publ. Agency.

- Ramachandra *et al.* 2018. *Breeding of Spices and Plantation crops*. Narendra Publishing House, New Delhi.
- Ranganathan V. 1979. *Hand Book of Tea Cultivation.* UPASI, Tea Res. Stn. Cinchona.
- Sera T, Soccol CR, Pandey A, Roussos S *Coffee Biotechnology and Quality*. Springer, Dordrecht.
- Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.
- Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
- Sharangi AB and Acharya SK. 2008. *Quality management of Horticultural crops*. Agrotech Publishing House, Udaipur; ISBN: 81-8321-090-2.
- Srivastava HC, Vatsaya and Menon, KKG. 1986. *Plantation Crops – Opportunities and Constraints.* Oxford and IBH.
- Thampan PK. 1981. *Hand Book of Coconut Palm*. Oxford and IBH.

I. Course Title : Production of Spice Crops

II. Course Code : PSM 502

III. Credit Hours : (2+1)

IV. Why this course ?

Spice crops play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers. This course will impart theoretical as well as hands-on experience to the learner on scientific production technology of various spice crops in Indian perspectives. It will provide comprehensive knowledge in this regard.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on various aspects of production technology of spice crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Spice Crops	I Role of spice crops II Classification of spice crops
2	Production Technology	I Varietal wealth II Propagation and nursery management III Agro techniques
3	Harvest and Post harvest management	I Maturity indices and harvest II Postharvest management

VI. **Theory**

Block 1: Importance of spice crops

Unit 1: Role of Spice crops: Introduction, importance of spice crops, pharmaceutical significance, historical accent, present status – national and international, future prospects, role of Spices board and other development agencies.

Unit 2: Classification of spice crops: Major spices, minor spices, seed spices, tree spices, herbal spices.

Block 2: Production Technology

Unit 1: Varietal wealth: Botany and taxonomy, species, cultivars, commercial varieties/ hybrids in spice crops.

Unit 2: Propagation and nursery management: Seed, vegetative and micro- propagation methods, nursery techniques and nursery management practices.

Unit 3: Agro techniques: Climatic and soil requirements, site selection, layout, sowing/ planting times and methods, seed rate and seed treatment, nutritional and irrigation requirements, intercropping, mixed cropping, intercultural operations, weed control, mulching, plant protection, precision farming, physiological disorders, protected cultivation, organic production practices.

Block 3: Harvest and Post harvest management

Unit 1: Maturity indices and harvest: Maturity indices, harvesting methods, harvesting seasons, mechanized harvesting.

Unit 2: Post harvest management: Post harvest management including primary processing, grading, packaging and storage, GMP in major spice crops.

Crops

Black pepper, small and large Cardamom, Turmeric, Ginger, Garlic, Coriander, Fenugreek, Cumin, Fennel, Ajwain, Saffron, Vanilla, Nutmeg, Clove, Cinnamon, Allspice, Tamarind, Garcinia, Curry leaf.

VII. Practical

- Identification of seeds and plants;
- Botanical description of plant;
- Varietal features;
- Planting material production;
- Field layout and method of planting;
- Cultural practices;
- Harvest maturity, harvesting;
- Drying, storage, packaging;
- Primary processing;
- GAP in spice crops;
- GMP in spice crops;
- Short term experiments on spice crops;
- Exposure visits to spice farms, research institutes.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

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

- Develop the technical skill in commercial cultivation of spice crops
- Be able to start spice-based enterprises

X. Suggested Reading

- Agarwal S, Sastry EVD and Sharma RK. 2001. *Seed Spices: Production, Quality, Export.* Pointer Publ.
- Arya PS. 2003. *Spice Crops of India.* Kalyani.
- 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 Research Institute, 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.
- Ponnuswami V *et al.* 2018. *Medicinal Herbs and Herbal Cure*. Narendra Publishing House, New Delhi.
- Pruthi JS. Ed. 1998. *Spices and Condiments.* National Book Trust.
- Pruthi JS. 2001. *Minor Spices and Condiments- Crop Management and Post HarvestTechnology*. ICAR.
- Purseglove JW, Brown EG, Green CL and Robbins SRJ. Eds. 1981. *Spices.* Vols. I, II. Longman. Ramachandra *et al.* 2018. *Breeding of Spices and Plantation crops*. Narendra Publishing House, New Delhi.
- Ravindran PN. 2000. *Black pepper, Piper nigrum*. CRC press. Ravindran PN. 2002. *Cardamom, the genusElettaria*. CRC press Ravindran PN. 2003. *Cinnamon and cassia.* CRC press Ravindran PN. 2004. *Ginger, the genus Zingiber*. CRC press Ravindran PN. 2007. *Turmeric, the genus curcuma*. CRC press Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI
- Shanmugavelu KG, Kumar N and Peter KV. 2002. *Production Technology of Spices and Plantation Crops.* Agrobios.
- Sharangi AB, Datta S and Deb P. 2018. Spices "*Agrotechniques for quality produce*". Apple Acadamic Press (Tylor and Francis Groups), New Jersey, USA.
- Sharangi AB. 2018. Indian Spices "*The legacy, production and processing of India's treasured export.*" Springer International publishing AG, Part of Springer Nature 2018, Cham, Switzerland.
- Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
- Sharangi AB and Acharya SK. 2008. *Quality Management of Horticultural crops*. Agrotech Publishing House, Udaipur; ISBN: 81-8321-090-2.

- 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.

I. Course Title : Production of Medicinal and Aromatic Crops

II. Course Code : PSM 503

III. Credit Hours : (2+1)

IV. Why this course ?

Medicinal and aromatic crops play an important role in the national economy of India. These crops also provide health security to all. This course will impart theoretical as well as hands-on experience to the learner on scientific production technology of various medicinal and aromatic crops in Indian perspectives. It will provide comprehensive knowledge in this regard.

V. Aim of the course

To impart comprehensive knowledge on the production technology of important medicinal and aromatic crops

The course is organized as follows:

No	Blocks	Units
1	Importance of Medicinal and Aromatic Crops	I Classification of medicinal and aromatic crops II Medicinal plant based industry III Aromatic plant based industry
2	Production technology	I Varietal wealth II Propagation and nursery management III Agro techniques
3	Harvest and Post harvest management	I Maturity indices and harvest II Post harvest management

Theory

Block 1: Importance of Medicinal and Aromatic Crops

Unit 1: Classification of medicinal and aromatic crops: Importance of medicinal plants, Importance of aromatic plants, Role in national economy, utility sectors of medicinal and aromatic crops, classification of medicinal and aromatic crops, role of institutions, Medicinal Plant Board and NGO’s in research and development of medicinal and aromatic crops.

Unit 2: Medicinal and plant based industry: Indian system of medicine, traditional systems of medicine, tribal medicine, medicinal industry, source of medicinal plants, area, production, export and import of major crops, problems, prospects and challenges, IPR issues.

Unit 3: Aromatic plant based industry: Essential oils, classification, physical and chemical properties and storage of essential oils. Indian perfumery industry, area, production, export and import status of major aromatic crops, history and advancements, problems, prospects and challenges, IPR issues.

Block 2: Production technology of medicinal and aromatic crops

Unit 1: Varietal wealth: Botany and taxonomy, species, cultivars, commercial varieties/ hybrids in medicinal and aromatic crops.

Unit 2: Propagation and nursery management: Seed, vegetative and micro- propagation methods, nursery techniques and nursery management practices.

Unit 3: Agro techniques: Climatic and soil requirements, site selection, layout, sowing/ planting times and methods, seed rate and seed treatment, nutritional and irrigation requirements, intercropping, mixed cropping, intercultural operations, weed control, mulching, plant protection.

Block 3: Harvest and Post harvest management

Unit 1: Maturity indices and harvest: Maturity indices, harvesting methods, harvesting seasons in medicinal and aromatic crops.

Unit 2: Post harvest management: Post harvest management including primary processing, extraction, grading, packaging and storage, GMP in medicinal and aromatic crops.

Crops

A. **Medicinal crops:** Senna, periwinkle, medicinal coleus, aswagandha, glory lily, sarpagandha, *Dioscorea* sp., *Aloe vera*, *Andrographis paniculata*, *Digitalis*, medicinal solanum, isabgol, opium poppy, safedmusli, *Stevia rebaudiana*, *Mucuna pruriens*, *Piper longum*, *Plumbago sp.*

B. **Aromatic crops:** Palmarosa, lemongrass, citronella, vetiver, mentha, patchouli, sweet flag, jasmine, tuberose, geranium, artemisia, lavender, *Ocimum* sp., eucalyptus, sandal

VI. Practical

- Description of botanical and varietal features;
- Nursery techniques;
- Lay out and planting;
- Manuring practices;
- Maturity standards;
- Harvesting;

- Primary processing;
- Extraction of oils;
- Herbarium preparation;
- Project preparation for establishing herbal gardens;
- GAP in medicinal and aromatic crops;
- GMP in medicinal and aromatic crops;
- Exposure visits to institutes, herbal gardens and industries.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

VIII. Learning outcome

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

- Develop the technical skill in commercial cultivation of medicinal and aromatic crops
- Be able to start medicinal and aromatic crop-based enterprises

IX. Suggested Reading

- Atal CK and Kapur BM. 1982. *Cultivation and Utilization of Medicinal Plants*. RRL, CSIR, Jammu.
- Barche S. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi.
- Das K. 2013. *Essential oils and their applications*. New India Publishing Agency, New Delhi Farooqi AA and Sriram AH. 2000. *Cultivation Practices for Medicinal and Aromatic Crops*. Orient Longman Publ.
- Farooqi AA, Khan MM and Vasundhara M. 2001. *Production Technology of Medicinal and Aromatic Crops.* Natural Remedies Pvt. Ltd.
- Gupta RK. 2010. *Medicinal and Aromatic plants*. CBS publications.
- Hota D. 2007. *Bio Active Medicinal Plants*. Gene Tech Books. Jain SK. 2000. *Medicinal Plants.*National Book Trust.
- Khan IA and Khanum A. 2001. *Role of Biotechnology in Medicinal and Aromatic Plants*. Vol. Vikaaz Publ.
- Kurian A and Asha Sankar M. 2007. *Medicinal Plants.* Horticulture Science Series, New India Publ. Agency.
- Panda H. 2002. *Medicinal Plants Cultivation and their Uses.* Asia Pacific Business Press. Panda H. 2005. *Aromatic Plants Cultivation, Processing and Uses.* Asia Pacific Business Press. Ponnuswami *et al.* 2018. *Medicinal Herbs and Herbal Cure*. Narendra Publishing House,

New Delhi.

- Prajapati SS, Paero H, Sharma AK and Kumar T. 2006. *A Hand book of Medicinal Plants*. Agro Bios.
- Ramawat KG and Merillon JM. 2003. *BioTechnology – Secondary Metabolites*. Oxford and IBH.
- Shankar SJ. 2018. *Comprehensive post harvest technology of flowers, medicinal and aromatic plants*. Narendra Publishing House, New Delhi.
- Skaria PB, Samuel M, Gracy Mathew, Ancy Joseph, Ragina Joseph. 2007. *Aromatic Plants*. New India Publ. Agency.

I. Course Title : Breeding of Plantation and Spice Crops

II. Course Code : PSM 504

III. Credit Hours : (2+1)

IV. Why this course ?

Plantation and spice crops play an important role in the national economy of India. For maximizing the production, productivity and quality of plantation and spice crops, fundamental knowledge on breeding methods of the major crops is essential. This course will impart theoretical as well as hands-on experience to the learner on reproductive biology, breeding methods and breeding achievements in various plantation and spice crops

V. Aim of the course

To impart comprehensive knowledge on the principles and practices in the breeding of important plantation and spice crops

The course is organized as follows:

No	Blocks	Units
1	Genetic diversity	I Species and cultivar diversity II Germplasm evaluation
2	Crop improvement	I Breeding objectives II Breeding methods
3	Breeding achievements and thrusts	I Breeding achievements future II Future thrusts

VI. Theory

Block 1: Genetic diversity

Unit I: Species and cultivar diversity: Floral and reproductive biology, cytogenetics, male sterility, incompatibility, wild and cultivated species, popular cultivars.

Unit II: Germplasm evaluation: Survey, collection, conservation and evaluation of germplasm.

Block 2: Crop improvement

Unit I: Breeding objectives: Breeding objectives/ goals on the basis of yield, quality, stress tolerance, adaptation.

Unit II: Breeding methods: Approaches for crop improvement, introduction, selection, hybridization, mutation breeding, polyploidy breeding, improvement of quality traits, resistance breeding for biotic and abiotic stresses.

Block 3: Breeding achievements and future thrusts

Unit I: Breeding achievements: Breeding achievements in terms of released varieties, parentage, salient features.

Unit II: Future thrusts: Molecular breeding and biotechnological approaches, marker-assisted selection, bioinformatics, breeding for climate resilience

Crops

A. **Plantation crops**: Coconut, Arecanut, Cashew, Cocoa, Rubber, Oil palm, Coffee, Tea, Palmyrah, Betel vine

B. **Spice crops**: Black pepper, small and large cardamom, Ginger, Turmeric, Fenugreek, Coriander, Fennel, Cumin, Ajwain, Garlic, Nutmeg, Cinnamon, Clove, Allspice, Garcinia, Tamarind

VII. Practical

- Characterization and evaluation of germplasm;
- Floral biology, anthesis; pollen behaviour, fruit set;
- Practices in hybridization, selfing and crossing techniques;
- Polyploidy breeding;
- Mutation breeding;
- Induction of somaclonal variation and screening the variants;
- Evaluation of biometrical traits and quality traits;
- Salient features of improved varieties and cultivars;
- Screening for biotic and abiotic stresses;
- Bioinformatics;
- Exposure visits to research institutes for plantation and spice crops.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

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

- Develop the technical skill in breeding of plantation and spice crops
- Be able to start plantation and spice crop-based seed production/ nursery centres

X. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*.

CRC Press. Anonymous. 1985. *Rubber and its Cultivation.* The Rubber Board of India.

- Chadha KL, Ravindran PN and Sahijram L. 2000. *Biotechnology in Horticultural and Plantation Crops*. Malhotra Publ. House.
- Chadha KL. 1998. *Advances in Horticulture*. Vol. IX,X. *Plantation and Spices Crops.* Malhotra Publishing House, New Delhi.
- Chadha KL and Rethinam P. Eds. 1993. *Advances in Horticulture.* Vol. IX. *PlantationCrops and Spices.* Part-I. Malhotra Publ. House.
- Chopra VL and Peter KV. 2002. *Handbook of Industrial Crops*. Haworth Press, USA and. Panama International Publ. (Indian Ed.).
- Choudappa P, Anitha K, Rajesh MK and Ramesh SV. 2017. *Biotechnology of Plantation Crops*. Daya Publishing House,New Delhi.
- Damodaran V K, Vilaschandran T and Valsalakumari PK. 1979. *Research on Cashew in India*. KAU, Trichur.
- Devi AR, Sharangi AB, Acharya SK and Mishra GC. 2017. *Coriander in Eastern India: The landraces and genetic diversity*. Krishi Sanskriti Publications. New Delhi. ISBN: 978-93-85822-48-3.
- *E-manual* on Advances in Cashew Production Technology. ICAR – Directorate of Cashew Research, Puttur –574 202, DK, Karnataka
- Harver AE. 1962. *Modern Coffee Production.* Leonard Hoff.
- Kumar N. 2017. *Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants*.CBS Publishers.
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- Panda H. 2016. The Complete Book on Cultivation and Manufacture of Tea (2nd Revised Edition). Asia Pacific Business Press Inc.
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- Ponnuswami *et al.* 2018. *Botany of Horticultural crops*. Narendra Publishing House, New Delhi Ponnuswami *et al.* 2018. *Spices*. Narendra Publishing House,New Delhi.
- Raj PS and Vidyachandra B. 1981. *Review of Work Done on Cashew*. UAS Research Series No.6, Bangalore.
- Ramachandra *et al*. 2018. *Breeding of Spices and Plantation Crops*. Narendra Publishing House,New Delhi
- Ravindran PN. 2002. *Cardamom, the genus Elettaria*. CRC press Ravindran PN. 2003. *Cinnamon and cassia.* CRC press Ravindran PN.

2004. *Ginger, the genus Zingiber*. CRC press Ravindran PN. 2007. *Turmeric, the genus Curcuma*. CRC press

- Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI
- Sera T, Soccol CR, Pandey A, Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
- Sethuraj MR and Mathew NT. 1992.*Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.
- Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
- Thampan PK. 1981. *Hand Book of Coconut Palm.* Oxford and IBH.

I. **Course Title : Breeding of Medicinal and Aromatic Crops**

II. **Course Code : PSM 505**

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

IV. **Why this course ?**

Medicinal and aromatic crops play an important role in the national economy of India. For maximizing the production, productivity and quality of medicinal and aromatic crops, fundamental knowledge on breeding methods of the major crops is essential. This course will impart theoretical as well as hands-on experience to the learner on reproductive biology, breeding methods and breeding achievements in various medicinal and aromatic crops.

V. **Aim of the course**

To impart comprehensive knowledge on the principles and practices in the breeding of important medicinal and aromatic crops.

The course is organized as follows:

No	Blocks	Units
1	Genetic diversity	1. Species and cultivar diversity 2. Germplasm evaluation
2	Crop improvement	1. Breeding objectives 2. Breeding methods
3	Breeding achievements and future thrusts	1. Breeding achievements 2. Future thrusts

VI. **Theory**

Block 1: Genetic diversity

Unit 1: Species and cultivar diversity: Floral and reproductive biology, cytogenetics, male sterility, incompatibility, wild and cultivated species, popular cultivars.

Unit 2: Germplasm evaluation: Survey, collection, conservation and evaluation of germplasm, IPR issues.

Block 2: Crop improvement

Unit 1: Breeding objectives: Breeding problems in medicinal and aromatic crops. Genetics of active principles, breeding objectives/ goals on the basis of yield, quality, stress tolerance, adaptation.

Unit 2: Breeding methods: Approaches for crop improvement, introduction, selection, hybridization, mutation breeding, polyploidy breeding, improvement of quality traits, resistance breeding for biotic and abiotic stresses.

Block 3: Breeding achievements and future thrusts

Unit 1: Breeding achievements: Breeding achievements in terms of released varieties, parentage, salient features.

Unit 2: Future thrusts: Molecular breeding and biotechnological approaches, marker-assisted selection, bioinformatics, breeding for climate resilience.

Crops

A. **Medicinal crops**: *Cassia angustifolia*, *Catharanthus roseus*, *Gloriosa superba*, *Coleus forskohlii*, *Stevia rebaudiana*, *Withania somnifera*, *Papaver somniferum*, *Plantago ovata*, *Chlorophytum* sp., *Rauvolfia serpentina*, *Aloe vera*, *Piper longum*, *Plumbago sp.*

B. **Aromatic crops**: Mint, geranium, patchouli, lemon grass, palmarosa, citronella, vetiver, Artemisia, ocimum, lavender, *Kaempferia galanga*, eucalyptus

VII. **Practical**

- Description of botanical features;
- Cataloguing of cultivars, varieties and species in medicinal and aromatic crops;
- Floral biology;
- Selfing and crossing;
- Evaluation of hybrid progenies;
- Induction of economic mutants;
- High alkaloid and high essential oil mutants;
- Evolution of mutants through physical and chemical mutagens;
- Introduction of polyploidy;
- Screening of plants for biotic and abiotic stress;
- *In-vitro* breeding in medicinal and aromatic crops.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

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

- Develop the technical skill in breeding of medicinal and aromatic crops
- Be able to start medicinal and aromatic crop-based seed production/ nursery centres

X. Suggested Reading

- Chadha KL and Gupta, R. 1995. *Advances in Horticulture*. Vol. XI. Malhotra Publ. House. Farooqi AA, Khan MM and Vasundhara M. 2001. *Production Technology of Medicinal and Aromatic Crops*. Natural Remedies Pvt. Ltd.
- Gupta R.K. 2010. *Medicinal and Aromatic plants*. CBS publications Jain SK. 2000. *Medicinal Plants*. National Book Trust.
- Julia F and Charters MC. 1997. *Major Medicinal Plants – Botany, Cultures and Uses*. Thomas Publ.
- Kurian A and Asha Sankar M. 2007. *Medicinal Plants*. Horticulture Science Series, New India Publ. Agency.
- Ponnuswami *et al.* 2018. *Blossom biology of Horticultural crops*. Narendra Publishing House, New Delhi
- Ponnuswami *et al.* 2018. *Botany of Horticultural crops*. Narendra Publishing House, New Delhi
- Ponnuswami *et al.* 2018. *Medicinal Herbs and Herbal Cure*. Narendra Publishing House, New Delhi
- Waghulkar VM. 2012. *Quality assurance techniques in pharmaceuticals*. New India Publishing Agency, New Delhi

I. Course Title : Systematics of Plantation and Spice Crops

II. Course Code : PSM 506

III. Credit Hours : (1+1)

IV. Why this course ?

Plantation and spice crops play an important role in the national economy of India. For the crop improvement programme of these crops, fundamental knowledge on origin and development, evolutionary process, taxonomy and cytogenetics and is most essential. This course will impart theoretical knowledge to the learner on the origin and distribution, evolutionary process, taxonomy and cytogenetics of various plantation and spice crops.

V. **Aim of the course**

To impart basic knowledge on the origin and development, evolutionary process, taxonomy, chemotaxonomy, cytogenetics and genetic resources of plantation and spice crops.

The course is organized as follows:

No	Blocks	Units
1	Origin and evolution	1. Centre of origin 2. Systematics
2	Genetic diversity	1. Species and cultivar diversity 2. Germplasm
3	Cataloguing	1. Descriptors 2. DUS guidelines

VI. **Theory**

Block 1: **Origin and evolution**

Unit I: Centre of origin: Centre of origin, distribution, phylogeny.

Unit II: Systematics: Botany, cytology, ploidy status, sex forms, flowering and pollination biology, cytogenetics.

Block 2: **Genetic Diversity**

Unit I: Species and cultivar diversity: Wild and related species, cultivars.

Unit II: Germplasm: Indigenous and exotic germplasm.

Block 3: **Cataloguing**

Unit I: Descriptors: Biovarsity/ NBPGR descriptors and their salient features.

Unit II: DUS guidelines: DUS guidelines, molecular aspects of systematics.

Crops

A. **Plantation crops**: Coconut, Arecanut, Oil Palm, Tea, Coffee, Cocoa, Cashew, Rubber, Betel Vine

B. **Spice crops**: Black Pepper, Small Cardamom, Ginger, Turmeric, Nutmeg, Cinnamon, Clove, Vanilla, Coriander, Fennel, Cumin, Fenugreek, Garlic

VII. **Practical**

- Genus, species and cultivar features of various plantation and spice crops;
- Characterization based on descriptors;
- Characterization based on DUS guidelines;
- Study of sex forms and floral biology;
- Study of molecular markers;
- Exposure visits to national institutes including NBPGR.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

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

- have thorough understanding on the systematics of plantation and spice crops

X. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press
- Chadha KL and Gupta R. 1995. *Advances in Horticulture*. Vol. XI. Malhotra Publ. House. Charles B. 1993. *Discussions in Cytogenetics*. Prentice Hall Publications,
- Diwan AP and Dhakad NK. 1996. *Genetics and Development*. Anmol Publications Private Limited, New Delhi.
- *E-manual* on Advances in Cashew Production Technology. ICAR – Directorate of Cashew Research, Puttur –574 202, DK, Karnataka
- Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.
- Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.
- Pillay PNR. 1980. *Handbook of Natural Rubber Production in India.* Rubber Research Institute, Kottayam. pp.668
- Ponnuswami *et al.* 2018. Blossom biology of Horticultural crops. Narendra Publishing House, New Delhi
- Ponnuswami *et al.* 2018. Botany of Horticultural crops. Narendra Publishing House, New Delhi Ravindran PN. 2000. *Black pepper*, *Piper nigrum*. CRC press
- Ravindran PN. 2002. *Cardamom, the genusElettaria*. CRC press Ravindran PN. 2003. *Cinnamon and cassia.* CRC press Ravindran PN. 2004. *Ginger, the genus Zingiber*. CRC press Ravindran PN. 2007. *Turmeric, the genus curcuma*. CRC press Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI
- Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
- Sethuraj MR and Mathew NT. 1992.*Natural Rubber: Biology, Cultivation and Technology* (*Developments in Crop Science*). Elsevier Science.

- Sharma G. 2009. *Systematics of fruit Crops*. New India Publishing House, India. Strickberger MW. 2005. *Genetics* (III Ed). Prentice Hall, New Delhi, India Tamarin RH. 1999. *Principles of Genetics*. Wm. C. Brown Publishers

I. **Course Title : Systematics of Medicinal and Aromatic Crops**

II. **Course Code : PSM 507**

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

IV. **Why this course ?**

Medicinal and aromatic crops play an important role in the national economy of India. For the crop improvement programme of these crops, fundamental knowledge on origin and development, evolutionary process, taxonomy and cytogenetics is most essential. This course will impart theoretical knowledge to the learner on the origin and distribution, evolutionary process, taxonomy and cytogenetics of various medicinal and aromatic crops.

V. **Aim of the course**

To impart basic knowledge on the origin and development, evolutionary process, taxonomy, cytogenetics and genetic resources of medicinal and aromatic crops.

The course is organized as follows:

No	Blocks	Units
1	Origin and evolution	I Centre of origin II Systematics
2	Genetic diversity	I Species and cultivar diversity II Germplasm
3	Cataloguing	I Descriptors II DUS guidelines

VI. **Theory**

Block 1: Origin and evolution

Unit I: Centre of origin: Centre of origin, distribution, phylogeny, chemotaxonomy.

I. **Theory**

Block 1: **Origin and evolution**

Unit I: **Centre of origin: Centre of origin, distribution, phylogeny, chemotaxonomy**

Unit II: Systematics: Botany, cytology, ploidy status, sex forms, flowering and pollination biology, cytogenetics.

Block 2: **Genetic Diversity**

Unit I: Species and cultivar diversity: Wild and related species, cultivars.

Unit II: Germplasm: Indigenous and exotic germplasm.

Block 3: **Cataloguing**

Unit I: Descriptors: Biovarsity/ NBPGR descriptors and their salient features.

Unit II: DUS guidelines: DUS guidelines, molecular aspects of systematics.

Crops

1. **Medicinal crops**: Opium poppy, Isabgol, Aswagandha, Senna, Medicinal coleus, Glory Lily, Periwinkle, Sarpagandha, Long Pepper, Stevia, Safed musli, *Plumbago sp.*
2. **Aromatic crops**: Lemongrass, Citronella, Palmarosa, Vetiver, Mint, Patcholi, Geranium, Ocimum, Rosemary, Lavender, *Kaempferia galanga*, Eucalyptus

II. **Practical**

- Genus, species and cultivar features of various medicinal and aromatic crops;
- Characterization based on descriptors;
- Characterization based on DUS guidelines;
- Study of sex forms and floral biology;
- Study of molecular markers;
- Exposure visits to national institutes including NBPGR.

III. **Teaching Methods/ Activities**

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IV. **Learning outcome**

After successful completion of this course, the students are expected to have thorough understanding on the systematics of medicinal and aromatic crops

V. **Suggested Reading**

- Birel Shah and Seth AK. 2005. *Text book of Pharmacognosy and Phytochemistry*. CBS Publishers and distributors, New Delhi.
- Charles Burnham. 1993. *Discussions in Cytogenetics*. Prentice Hall Publications
- Diwan AP and Dhakad NK. 1996. *Genetics and Development*. Anmol Publications Private Limited, New Delhi.
- Farooqi AA, Khan MM and Vasundhara M. 2001. *Production Technology of Medicinal and Aromatic Crops.* Natural Remedies Pvt. Ltd.
- Gupta RK. 2010. *Medicinal and Aromatic plants*. CBS publications
- Prajapati ND, Purohit SS, Sharma AK, Kumar T. 2006. *A Hand book of Medicinal Plants.* Agro Bios (India).
- Ponnuswami *et al.* 2018. *Blossom biology of Horticultural crops*. Narendra Publishing House, New Delhi.
- Ponnuswami *et al*. 2018 *Botany of Horticultural crops*. Narendra Publishing House, New Delhi Raju R Wadekar. 2015. *Pharmacognosy and phytochemistry*, Event publishing house
- Ranjal Kandall. *Bioactive compounds and genomic study of medicinal plants*. LAMBERT Academic Publishing
- Sharma G. 2009. *Systematics of fruit Crops*. New India Publishing House, India. Skaria P Baby *et al.* 2007. *Aromatic Plants*. New India Publ. Agency.
- Strickberger MW. 2005. *Genetics* (III Ed). Prentice Hall, New Delhi, India Tamarin RH. 1999. *Principles of Genetics*. Wm. C. Brown Publishers.
- Thakur RS, Pauri HS and Hussain A. 1989. *Major Medicinal Plants of India*. CSIR.

I. **Course Title : Underexploited Plantation, Spice, Medicinal and Aromatic Crops**

II. **Course Code : PSM 508**

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

IV. **Why this course ?**

There are many number of underexploited plantation, spice, medicinal and aromatic crops which are becoming important in line with the major ones. They could very well be the major crops of tomorrow. This course will impart comprehensive knowledge to the learner on the importance and scientific production technology of various under utilised plantation, spice, medicinal and aromatic plants in India.

V. **Aim of the course**

To facilitate understanding on the importance and cultivation of underutilized and lesser known plantation, spice, medicinal and aromatic plants. The course is organized as follows:

No	Blocks	Units
1	Importance and status	I Importance and uses
	II Status and future prospects	
	Production technology	I Propagation and varieties II
	Agro techniques	
3	Harvest and post harvest	I Harvest indices management
	II Post harvest management	

VI. **Theory**

Block 1: Importance and status

Unit I: Importance and Uses: Introduction, importance, economic parts used, traditional uses.

Unit II: Status and future prospects: Present status, origin, distribution and future prospects of under exploited PSMAs.

Block 2: Production technology

Unit I: Propagation and varieties: Propagation and nursery techniques, species varieties.

Unit II: Agro techniques: Climatic and soil requirements, planting and after care, weed and water management, manuring, plant protection.

Block 3: Harvest and post harvest management

Unit I: Harvest indices: Maturity indices, harvesting time, techniques, crop duration.

Unit II: Post harvest management: Primary processing, extraction and value addition, storage, active ingredients.

Crops

A. **Plantation crops**: Wattle, minor species of Areca, Coffea, Hevea

B. **Spice crops**: *Illicium verum*, *Myristica malabarica*, *M. beddomei*, *Cinnamomum tamala*, *C. malabatrum*, *Xanthoxylum* sp., *Curcuma caesia*, *C. aromatica*, *C. zedoaria*, *C. amada*, *Anethum graveolense*, *Hyssopus officinalis*, *Eringiumfoetidum*, *Pimpinella anisum*, *Artocarpus lacucha*.

C. **Medicinal plants**: *Flacourtia montana*, *Plectranthus aromaticus*, *Adhatoda* sp. *Hemidesmus indicus*, *Tinospora cordifolia*, *Gymnema sylvestre*, *Psoralea corylifolia*, *Eclipta alba*, *Aristalochia indica*, *Morinda citrifolia*, *Caesalpinia sappan*, *Terminalia chebula*, *T. bellerica*, *Phyllanthus amarus*, *Strychnos nuxvomica*, *S. indicum*, *S. xanthocarpum*, *Aegle marmelos*, *Alpinia* sp., *Hibiscus subdariffa*, *Anthocephalus kadamba*, *Costus* sp., *Kaempferia rotunda*, *K. parviflora*, *Picrorrhiza kurroa*, *Nardostachis jatamansi*,*Valeriana officinalis*, *Swertia chiraita*, *Aconitum* sp., *Salvia officinalis*, *Centella asiatica*, *Bixa orellana*, *Bacopa monnieri*

D. **Aromatic plants**: *Bursera* sp., *Commiphora wightii*, *Ocimum kilimandjaricum*, *Melaleuca*, *Michaelia champaka*, *Rosa damascena*, *Cananga odorata*, marjoram, chamomile

VII. Practical

- Botanical characteristics of species and varieties of various underexploited plantation, spice, medicinal and aromatic plants;
- Economic parts and their products;
- Propagation and nursery techniques;
- Harvesting and primary processing of under utilised PSMAs;
- Exposure visits to institutes, botanical gardens, herbal gardens and distillation units.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

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

- be thorough with the importance and commercial production technology of underutilized and lesser known plantation, spice, medicinal and aromatic plants.
- be able to start underutilized and lesser known plantation, spice, medicinal and aromatic plants-based enterprises

X. Suggested Reading

- Atal CK and Kapur BM. *Cultivation and Utilization of Aromatic plants*. R.R.L. Jammu Barche Swati. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi

- Chadha KL and Gupta R. 1995. *Advance in Horticulture.* Vol. XI. *Medicinal and AromaticPlants.* Malhotra Publ. House.
- CSIR, *The Wealth of India*. Volume A-Z CSIR
- Farooqui AA, Khan MM and Sreeramu BS. 1997. *Cultivation of Medicinal and Aromatic Crops in India.* Naya Prokash.
- Jain SK. 1979. *Medicinal Plants.* National Book Trust.
- Kurian A and Asha Sankar M. 2007. *Medicinal Plants.* Horticulture Science Series, New India Publ. Agency.
- Nybe EV, Mini Raj N and Peter KV. 2007. *Spices*. Horticulture Science Series, New India Publ. Agency.
- Peter KV. *Under exploited and underutilized Horticulture crops*. Volume I-IV. New India Publication Agency.
- Ponnuswami *et al.* 2018. *Blossom biology of Horticultural crops*. Narendra Publishing House, New Delhi.
- Ponnuswami *et al.* 2018. *Botany of Horticultural crops*. Narendra Publishing House, New Delhi Ponnuswami *et al*. 2018. *Medicinal Herbs and Herbal Cure*. Narendra Publishing House, New Delhi
- Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
- Sharangi AB, Bhutia PH, Chandani Raj A and Sreenivas M. 2018. *Underexploited spice crops: Present status, agrotechnology and future research directions.* Apple Academic Press (Taylor and Francis Group), Waretown, NJ, USA, p.326.
- Sivarajan VV and Balachandran I. 1994. *Ayurvedic Drugs and their Plant Sources*. Oxford and IBH.

I. Course Title : Growth and Development of Plantation, Spice, Medicinal and Aromatic Crops

II. Course Code : PSM 509

III. Credit Hours : (2+1)

IV. Why this course ?

Understanding on growth and development of plantation, spice, medicinal and aromatic crops is vital towards quality production as well as yield. Fundamental knowledge on developmental physiology, biology and biochemistry and the associated changes is most essential. This course will impart theoretical as well as hands-on experience to the learner on these aspects of PSMA crops for improving their productivity.

V. Aim of the course

To impart comprehensive knowledge on the growth, developmental stages and crop regulation to increase the productivity in PSMAs

The course is organized as follows:

No	Blocks	Units
1	Growth and development	I Stages of growth II Growth pattern III Assimilate partitioning
2	Canopy management	I Canopy management II Plant bio regulators
3	Developmental physiology and biochemistry	I Vegetative phase II Flowering and fruit set III Growth and development during stress

VI. Theory

Block 1: Growth and development

Unit I: Stages of growth: Growth and development, definitions, components, photosynthetic productivity, different stages of growth, growth curves, growth analysis, morphogenesis in PSMAs.

Unit II: Growth pattern: in annual, semi-perennial and perennial crops, growth dimorphism, environmental impact on growth and development: effect of light, temperature, photoperiod.

Unit III: Assimilate partitioning: Assimilate partitioning during growth and development, influence of water and mineral nutrition.

Block 2: Canopy management

Unit I: Canopy management: Canopy management for conventional and high density planting pruning, training, chemicals, crop regulation for year round and off season production in PSMAs.

Unit II: Plant bio regulators: plant bio regulators- auxins, gibberellins, cytokinins, ethylene, inhibitors and retardants, basic functions, biosynthesis and role in crop growth and development.

Block 3: Developmental physiology and biochemistry

Unit I: Vegetative phase: Developmental physiology and biochemistry during dormancy, bud break, juvenility.

Unit II: Flowering and fruit set

Physiology of flowering, photoperiodism, vernalisation, effect of temperature, heat units, thermoperiodism, pollination, fertilisation, fruit set, fruit drop, fruit growth, ripening, seed development in PSMAs.

Unit III: Growth and development process during stress: Growth and development process during stress, production of secondary metabolites, molecular and genetic approaches in growth and development.

VII. Practical

- Dormancy mechanisms in seeds, seed rhizomes;
- Techniques of growth analysis;
- Evaluation of photosynthetic efficiency under different environments;
- Technologies for crop regulation in cashew, coffee, cocoa, etc.;
- Root shoot studies, flower thinning, fruit thinning;
- Crop regulation for year round production;
- Use of growth regulators in PSMA crops.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Demonstrations
- Exposure visits

IX. Learning outcome

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

- have thorough understanding on growth and development of PSMA crops
- will enable them to formulate crop regulation strategies for productivity enhancement.

X. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press
- Buchanan BW. Gruiessam and Jones, R. 2002. *Biochemistry and Molecular Biology of Plants*. John Wiley and Sons.
- *E- manual* on Advances in Cashew Production Technology. ICAR - Directorate of Cashew Research, Puttur –574 202, DK, Karnataka
- Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*.Wiley.
- Fosket DE. 1994. *Plant Growth and Development: A Molecular approach*. Academic Press. Leoplod AC and Kriedermann PE. 1985. *Plant Growth and Development.* 3rdEd.McGraw-Hill Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.
- Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.
- Pillay PNR. 1980. *Handbook of Natural Rubber Production in India.* Rubber Research Institute, Kottayam. pp.668
- Ravindran PN. 2000. *Black pepper, Piper nigrum*. CRC press Ravindran PN. 2002. *Cardamom, the genus Elettaria*. CRC press Ravindran PN. 2003. *Cinnamon and cassia*. CRC press Ravindran PN. 2004. *Ginger, the genus Zingiber*. CRC press Ravindran PN. 2007. *Turmeric, the*

genus curcuma. CRC press

- Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI
- Roberts JS Downs and P Parker. 2002. *Plant Growth Development*. In: *Plants* (L. Ridge, Ed.), pp. 221-274, Oxford University Press
- Salisbur FB and Ross CW. 1992. *Plant Physiology*. 4th Ed. Wadsworth Publ.
- Sera T, Soccol CR, Pandey A. and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
- Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.

I. Course Title : Biochemistry of Plantation, Spices, Medicinal and Aromatic Crops

II. Course Code : PSM 510

III. Credit Hours : (2+1)

IV. Why this course ?

Postharvest physiology and biochemistry of plantation, spice, medicinal and aromatic crops contributes immensely towards quality improvement in crude as well as processed products. Fundamental knowledge on biochemistry of various crops is also essential for formulating their management practices in the field. This course will impart theoretical as well as hands-on biochemistry of PSMA crops

I. Aim of the course

To impart comprehensive knowledge on the biochemistry, production of primaryand secondary metabolites and the extraction of bioactive principles from PSMAs

The course is organized as follows:

No	Blocks	Units
1 `	Post harvest physiology	I Physiological and biochemical changes
II	Contaminants	
2	Value addition	I Value added products II Quality standards
3	Extraction techniques	I Extraction techniques
II	Plant tissue culture	

II. Theory

Block 1: Post-harvest physiology

Unit I: Physiological and biochemical changes: Maturity indices, changes during ripening, processing, factors affecting quality. Secondary metabolites and their biosynthetic pathways, factors affecting production of secondary metabolites.

Unit II: Contaminants: Adulterants, and substitutes, sources of contamination- microbial, heavy metal, pesticide residues in PSMAs.

Block 2: Value addition

Unit I: Value added products: Fixed oils, essential oils, dyes, oleoresins, aroma chemicals and other value added products, their content, storage, medicinal and pharmacological properties, use in the food, flavour perfumery and pharmaceutical industries.

Unit II: Quality standards: Quality standards of raw materials and finished products.

Block 3: Extraction techniques

Unit : Extraction methods: Basic and advanced extraction techniques in PSMAs-Soxhlet, SCFE, Membrane extraction. Chemical characterization-HPTLC, GCMS, LCMS, NMR

Unit II: Plant tissue culture: Plant tissue cultures in the industrial production of bioactive plant metabolites. Cell suspension culture systems for large scale culturing of plant cells and production of secondary metabolites. Advantages of cell culture over conventional extraction techniques.

III. Practical

- Biochemical characterisation;
- Detection of adulterants and substitutes;
- Extraction and quantification of secondary metabolites;

- Chromatographic separation of the products;
- Quality assurance;
- Testing the product;
- Exposure visit to leading industries;
- Assessment of antimicrobial properties;
- *In-vitro* production of secondary metabolites.

IV. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

V. Learning outcome

After successful completion of this course, the students are expected to develop the technical know- how on postharvest biochemistry of plantation, spice,medicinal and aromatic crops.

VI. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.
- Daniel M and Mammen D. 2016. *Analytical methods for medicinal plants and economic botany*. Scientific publishers.
- Das K. 2013. *Essential oils and their applications*. New India Publishing Agency, New Delhi.
- *E-manual* on Advances in Cashew Production Technology. ICAR - Directorate of Cashew Research, Puttur –574 202, DK, Karnataka.
- Hammon JM and Yusibov V. 2000. *Plant Biotechnology*: New Products and application. Springer- Verlag.
- Orhan I. 2012. *Biotechnological Production of Plant Secondary Metabolites*. Bentham Science Publishers.
- Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.
- Panda H. 2016. The Complete Book on Cultivation and Manufacture of Tea (2nd Revised Edition). Asia Pacific Business Press Inc.
- Parimelzhagan T. 2013. *Turning plants into medicines: Novel approaches*. New India Publishing Agency, New Delhi.
- Pillay PNR. 1980. *Handbook of Natural Rubber Production in India*. Rubber Research Institute, Kottayam. pp.668.

- Ponnuswami *et al*. 2018 Medicinal Herbs and herbal cure. Narendra Publishing House, New Delhi.
- Raaman N. 2006. *Phytochemical techniques*. New India Publishing Agency, New Delhi. Raju R Wadekar. 2015. *Pharmacognosy and phytochemistry*, Event publishing house.
- Ramawat KG. 2007. *Biotechnology: secondary metabolites: plants and microbes*. Science Publishers.
- Ranjal Kandall. *Bioactive compounds and genomic study of medicinal plants*. LAMBERT Academic Publishing.
- Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
- Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.
- Shah B and Seth AK. 2005. *Text book of Pharmacognosy and Phytochemistry*. Cbs Publishers and distributors, New Delhi.
- Shankar SJ. 2018. Comprehensive post harvest technology of flowers, medicinal and aromatic plants. Narendra Publishing House, New Delhi
- Shukla YM. 2009. *Plant secondary metabolites*. New India Publishing Agency, New Delhi Syed Aftab Iqbal and Noor Ahmed Khan. 1993.*Text book of Phytochemistry*. Discovery Publishing house Pvt. Ltd.
- Tiwari C. 2018. *Antimicrobial properties of Medicinal plants*. Narendra Publishing House, New Delhi.
- Trivedi C. 2004. *Herbal drugs and biotechnology*. Pointer Publishers.
- Waghulkar VM. 2012. *Quality assurance techniques in pharmaceuticals*. New India Publishing Agency, New Delhi.

I. Course Title : Biodiversity and Conservation of Plantation, Spice Medicinal and Aromatic Crops

II. Course Code : PSM 511

III. Credit Hours : (2+1)

IV. Why this course ?

India is the homeland of several plantation, spice, medicinal and aromatic crops. Biodiversity conservation is considered as the primary step in protecting the gene pool available in these crops. Fundamental knowledge on centres of diversity, germplasm evaluation, documentation, data base management and cataloguing is most essential. This course will impart theoretical as well as hands-on eXperience to the learner on these areas.

V. Aim of the course

To impart basic knowledge on natural as well as agro bio diversity, its value and conservation strategies with respect to PSMAs.

The course is organized as follows:

No	Blocks	Units
1	Plantation and spice crops	I Biodiversity II Germplasm collection and quarantine III Documentation and cataloguing IV National and international issues
2	Medicinal and aromatic crops	I Biodiversity II Germplasm collection and quarantine III Documentation and cataloguing IV National and international issues

VI. Learning outcome

After successful completion of this course, the students are eXpected to develop thorough understanding on biodiversity conservation of plantation, spice, medicinal and aromatic plants.

VII. Theory

Block 1: Plantation and Spice crops

Unit I: Biodiversity: Biodiversity, issues and goals, centres of origin of Plantation and spice crops, primary and secondary centres of genetic diversity.

Unit II: Germplasm collection and quarantine: EXploration and germplasm collection, planning and logistics, eXchange of germplasm, plant quarantine principles, regulations plant quarantine systems in India. Components of germplasm evaluation, descriptor lists. Conservation of genetics resources, Concept of base and active collections, long and short term storage of Plantation and spice crops, gene bank management.

Unit III: Documentation and cataloguing: Recent approaches and role of biotechnology in PGR conservation documentation and data base management, cataloguing gene bank information. Molecular markers in characterisation of plant genetic resources. GIS in biodiversity mapping.

Unit IV: National and international issues: Genetic resources management of Plantation and Spice crops in India and in International perspective. Utilization and achievements in major crops. Concepts of rarity, threat, endangerment and extinction in major plantation and spice crops. Bio diversity concerns, national and international regulations, conservation networks. Good collection practices, domestication, PPV and FRA and DUS testing. Geographical indication, Biodiversity act and biodiversity legislations.

Block II: Medicinal and aromatic crops

collection, planning and logistics, exchange of germplasm, plant quarantine principles, regulations plant quarantine systems in India. Components of germplasm evaluation, descriptor lists. Conservation of genetics resources, Concept of base and active collections, long and short term storage of Plantation and spice crops, gene bank management.

Unit III: Documentation and cataloguing: Recent approaches and role of biotechnology in PGR conservation documentation and data base management, cataloguing gene bank information. Molecular markers in characterisation of plant genetic resources. GIS in biodiversity mapping.

Unit IV: National and international issues: Genetic resources management of Plantation and Spice crops in India and in International perspective. Utilization and achievements in major crops. Concepts of rarity, threat, endangerment and extinction in major plantation and spice crops. Bio diversity concerns, national and international regulations, conservation networks. Good collection practices, domestication, PPV and FRA and DUS testing. Geographical indication, Biodiversity act and biodiversity legislations.

VIII. Practical

- Collection and identification of different plantation, spice, medicinal and aromatic plants from natural sources;
- Preparation of herbarium;
- Botanical and phyto-chemical grouping of PSMAs;
- Classification of PSMAs based on plant parts used;

- Documentation of germplasm;
- Maintenance of passport data and other records;
- Field explorations;
- Detection of adulterants and substitutes in PSMAs;
- Ethno botanical studies in tribal areas;
- Planning and layout of herbal gardens;
- Exposure visits to herbaria, herbal gardens and important organisations engaged in collection and utilization of PSMAs.

IX. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Demonstrations
- Exposure visits

X. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press
- Choudhari AB. *Megadiversity Conservation: Flora, Fauna and Medicinal Plants of India's hot spots.*
- Devi AR, Sharangi AB, Acharya SK and Mishra GC. 2017. *Coriander in Eastern India: The landraces and genetic diversity*. Krishi Sanskriti Publications. New Delhi. ISBN: 978-93- 85822-48-3.
- *E- manual* on Advances in Cashew Production Technology. ICAR -Directorate of Cashew Research, Puttur –574 202, DK, Karnataka
- Kassahun Beemnet, Jemal Omar Sherif, TessemaTsion, Abate Solomon. 2009. *Production, Processing and utilization of Aromatic Plants*. EIAR.
- Khan JB and Singh GP. 2012. *Biodiversity Management and Conservation* LAMBERT Negi SS. *Biodiversity of India and its Conservation.*
- Panda H. 2002. *Medicinal Plants Cultivation and their Uses.* Asia Pacific Business Press. Panda H. 2005. *Aromatic Plants Cultivation, Processing and Uses.* Asia Pacific Business Press Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.
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Utilisation and Applications. Discovery publishing house, New Delhi

- Pillay PNR. 1980. *Handbook of Natural Rubber Production in India.* Rubber Research Institute, Kottayam. pp.668
- Ponnuswami *et al.* 2018. Medicinal Herbs and herbal cure. Narendra Publishing House, New Delhi
- Ponnuswami *et al.* 2018. Spices. Narendra Publishing House, New Delhi Pullaiah T. 2011. *Biodiversity in India* Vol.5.Daya Publishing house
- Rajak RC and Rai MK. *Herbal Medicines*, *Biodiversity and Conservation strategies*. IBH. Ramakrishnan N. 2018. *Biodiversity in Indian Scenario*. Daya publishing house.
- Sera T, Soccol CR, Pandey A, Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
- Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.
- Thirugnanakumar. 2018. *Genetic diversity and phenotypic stability in crop plants*. New India Publishing Agency, New Delhi
- Trivedi PC. *Medicinal Plants: Utilization and Conservation.*

Course Title with Credit Load for Ph.D. (Hort.) in Plantation, Spices, Medicinal andAromatic Crops

*Compulsory among major courses

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
PSM 601*	Advances in Production of Plantation and Spice Crops	3+0
PSM 602*	Advances in Production of Medicinal and Aromatic Crops	3+0
PSM 603*	Recent Breeding Approaches in Plantation, Spice,	3+0
PSM 604	Advanced Methods in Laboratory Techniques in PSMA crops	1+2
PSM 605	Biotechnological Approaches in PSMA Crops	3+0
PSM 606	Abiotic Stress Management in Plantation, Spice, Medicinal	2+1
PSM 607	Organic Spice and Plantation Crops Production	2+1
PSM 608	Marketing and Trade of Plantation, Spice, Medicinal	2+1
	Minor courses	06
	Supporting courses	05
PSM 691	Seminar-I	0+1
PSM 692	Seminar-II	0+1
PSM 699	Research	0+75
	Total	**100**

I. Course Title : Advances in Production of Plantation and Spice Crops

II. Course Code : PSM 601

III. Credit Hours : (3+0)

IV. Why this course ?

Plantation and spice crops play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers. This course will impart knowledge to the learner on advanced scientific production technology of various plantation and spice crops in Indian perspectives. Hi-tech production technologies will be discussed in this course.

V. Aim of the course

The course is designed to provide advanced crop production techniques of various plantation and spice crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Plantation and productivity: Indian and spice scenario	I. Area, production, Crops world II. Export potential III. Promotional programmes
2	Advanced agro techniques material	I. Varietal wealth and planting production II. Mass multiplication techniques III. Hi-tech nursery techniques IV. Impact of climate change
3	Harvest and post harvest indices and harvest management harvest management	I. Maturity II. Post- III. Quality standards

VI. Theory

Block 1: Importance of Plantation and Spice Crops

Unit I: Area, production, productivity: Indian and world scenario: Role of plantation and spice crops in national economy, area-production statistics at national and international level, productivity challenges, industrial requirement of plantation and spice crops, demand-supply scenario of plantation and spice crop. Export potential: Export scenario, market opportunities and challenges in plantation and spice crops, global imports and exports, export of organic produce and products.

Unit III: Promotional programmes: Role of commodity boards and directorates in the development programmes of plantation and spice crops, contract farming, Farmer Producer Organizations (FPO) and Farmer Producer Companies (FPC).

Block 2: Advanced Agrotechniques

Unit I: Varietal wealth and planting material production: Cultivars and improved varieties in plantation and spice crops, mass multiplication techniques, hi-tech nursery techniques.

Unit II: Agrotechniques: Precision farming techniques, HDP systems, fertigation, chemical regulation of crop productivity, protected cultivation of high value crops, mechanization in plantation and spice crops, hydroponics, aeroponics, application of nanotechnology, robotics.

Unit III: Impact of climate change: Impact of biotic and abiotic factors on growth and productivity, climate resilient technologies in plantation and spice crops, soil health management, organic production systems.

Block 3: Harvest and postharvest management

Unit I: Maturity indices and harvest: Influence of pre and post harvest factors on quality of plantation and spice crops, pre and post harvest management techniques for improving quality, good manufacturing practices in plantation and spice sector.

Unit II: Quality standards: Domestic and international standards, HACCP, Coconut, Arecanut, Oil palm, Cashew, Coffee, Tea, Cocoa, Rubber, Palmyrah, Black pepper, Cardamom, Ginger, Turmeric, Nutmeg, Cinnamon, Clove, Vanilla, Garcinia, Coriander, Cumin, Fennel, Fenugreek, Ajwain, Dill, Saffron

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Presentation of review papers and research articles
- Exposure visits to research centres, industries

VIII. Learning outcome

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

- be equipped with the latest research outcome in commercial cultivation of plantation and spice crops
- be able to start hi-tech plantation and spice crop based enterprises

IX. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press Agarwal S, Divkarasastry EV and Sharma RK. 2001. *Seed Spices, Production, Quality and Export*. Pointer Publ.
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- Peter KV. 2001. *Hand Book of Herbs and Spices*. Vols. I-III. Woodhead Publ. Co., UK and CRC, USA.
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- Ranganathan V. 1979. *Hand Book of Tea Cultivation*. UPASI, Tea Res. Stn. Cinchona. Ravindran PN. 2003. *Cinnamon and cassia*. CRC press.
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- Ravindran PN. 2001. *Monograph on Black Pepper*. CRC Press. Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI
- Ravindran PN and Madhusoodanan KJ. 2002. *Cardamom, the Genus Elettaria*. CRC press. Sera T, Soccol CR, Pandey A and Roussos S Coffee Biotechnology and Quality. Springer, Dordrecht.
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- Shanmugavelu KG, Kumar N and Peter KV. 2002. *Production Technology of Spices and Plantation Crops*. Agrobios.
- Sharangi AB and Acharya SK. 2008. *Quality management of Horticultural crops*. Agrotech Publishing House, Udaipur; ISBN: 81-8321-090-2
- Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
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- Swain SC. 2018. *Precision Farming in Horticulture: Approaches and strategies*. Narendra Publishing House, New Delhi.
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- Winton AL and Winton KB. 1931. *The Structure and Composition of Food*. John Wiley and Sons.
- Yagna Narayan Ayer AK. 1960. *Cultivation of Cloves in India*. ICAR.

I. **Course Title** : **Advances in Production of Medicinal and Aromatic Crops**

II. **Course Code** : **PSM 602**

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

IV. **Why this course ?**

Medicinal and aromatic crops play an important role in the national economy of India. They also cater to the primary health care needs of a large section of people. This course will impart knowledge to the learner on advanced scientific production technology of various medicinal and aromatic crops in Indian perspectives.

V. **Aim of the course**

The course is designed to provide latest developments and trends in the production technology of various medicinal and aromatic crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Medicinal and Aromatic Crops	1. Biodiversity of medicinal and aromatic crops 2. Area, production, productivity statistics 3. Export potential
2	Advanced Agro techniques	1. Domestication studies 2. Varietal wealth and planting material production 3. Agro techniques 4. Impact of climate change
3	Harvest and post harvest Management	1. Maturity indices and Harvest 2. Modern methods of extraction of MAPs 3. Quality standards

VI. **Theory**

Block 1: Importance of Medicinal and Aromatic Crops

Unit I: Biodiversity of medicinal and aromatic crops (MAPs): Biodiversity of MAPs, conservation networks, global initiatives on medicinal plants conservation and development, World history on usage of MAPs, preference to natural products. Indian traditional wisdom and heritage, Indian herbal wealth, documentations, databases, scientific validation.

Unit II: Area, production and productivity statistics: Role of medicinal and aromatic crops in national economy, area-production statistics at national and international level, productivity challenges, Trends in food, flavouring, perfumery and cosmetic industries, requirement in the ayurvedic, pharmaceutical, perfume and cosmetic industries, demand-supply scenario of MAPs.

Unit III: Export potential: Export and import of crude drugs, standardized extracts, aromatic plants, essential oils. Intellectual Property Rights, patents. Contract farming. Role of Medicinal Plant Board in promotional programmes of MAPs.

Block 2: Advanced agro-techniques

Unit I: Domestication of medicinal and aromatic crops: Need for domestication, changes on domestication, influence of environment on secondary metabolite production, developing cultivation packages for emerging crops.

Unit II: Varietal wealth and planting material production: Cultivars and improved varieties in medicinal and aromatic crops, mass multiplication techniques, micropropagation, hi-tech nursery techniques.

Unit III: Agro techniques: Advanced research in the field of growth and development, nutrition and irrigation requirements, inter culture, mulching, weed control.

Precision farming techniques, HDP systems, fertigation, chemical regulation of crop productivity, protected cultivation of high value crops, hydroponics, aeroponics, application of nanotechnology, nano- fertilizers, nano-pesticides, robotics.

Unit IV: Impact of climate change: Impact of biotic and abiotic factors on growth, productivity and quality, climate resilient technologies in medicinal and aromatic crops, soil health management, organic production systems.

Block 3: Harvest and post harvest management

Unit I: Maturity indices and harvest: Influence of pre and post harvest factors on quality of medicinal and aromatic crops, pre and post harvest management techniques for improving quality, good manufacturing practices in herbal sector.

Unit II: Modern methods of extraction of MAPs: Advanced essential oil extraction and value addition methods in aromatic plants, advances in phytochemical extraction technologies, separation of bio-molecules, phytochemicals and drug development. Pharmacology and pharmacognosy, *in vivo* and *in-vitro* extraction of secondary metabolites, bioreactors.

Unit III: Quality standards: Quality standards in medicinal and aromatic plants, quality standards in crude drugs and finished products, use of aroma chemicals, aroma therapy, advanced research in biomedicines, nutraceuticals and natural drugs, American, European and Asian legislations on plant drugs, domestic and international standards, modern packaging techniques.

Crops

A. **Medicinal crops**:

Coleus, Glory lily, Senna, Periwinkle, Stevia, Aswagandha, Sarpagandha, Aloe, *Phyllanthus amarus*,. *Andrographis paniculata*, Isabgol, Poppy, *Digitalis* sp., *Commiphora* sp., Ipecac, Henbane, *Ocimum* sp., Centella, Bacopa, *Plumbago* sp. Saraca, Valerian, Jatamansi, Aconits, Ephedra and Bael.

B. **Aromatic crops**: Palmarosa, Lemongrass, Citronella, Vetiver, Geranium, Artemisia, Mint, Eucalyptus, Rosemary, Thyme, Patchouli, Rose, Jasmine, Tuberose Lavender.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Presentation of review papers and research articles
- Exposure visits to research centres, industries

VIII. Learning outcome

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

- be equipped with the latest research out come in commercial cultivation of medicinal and aromatic crops
- be able to start hi-tech medicinal and aromatic crop based enterprises

IX. Suggested Reading

- Dharamvir H. 2007. *Bioactive Medicinal Plants*. Gene Tech Books.
- Farooqi AA and Sriramu AH. 2000. *Cultivation Practices for Medicinal and Aromatic Crops*. Orient Longman Publ.
- Farooqi AA, Khan MM and Vasundhara M. 2001. *Production Technology of Medicinal and Aromatic Crops*. Natural Remedies Pvt. Ltd.
- Jain SK. 2000. *Medicinal Plants*. National Book Trust.
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Book of Medicinal Plants. Agro Bios.

- Ramawat KG and Merillon JM. 2003. *Biotechnology–Secondary Metabolites*. Oxford and IBH.
- Shankar SJ. 2018. *Comprehensive post harvest technology of flowers, medicinal and aromatic plants*. Narendra Publishing House, New Delhi.
- Sharangi AB and Acharya SK. 2008. *Quality management of Horticultural crops*. Agrotech Publishing House, Udaipur; ISBN: 81-8321-090-2.
- Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
- Swain SC. 2018. *Precision farming in Horticulture: Approaches and strategies*. Narendra Publishing House, New Delhi.
- Tiwari C. 2018. *Antimicrobial properties of Medicinal plants*. Narendra Publishing House, New Delhi.

I. Course Title : Recent Breeding Approaches in Plantation, Spice,Medicinal and Aromatic Crops

II. Course Code : PSM 603

III. Credit Hours : 3+0

IV. Why this course ?

Plantation, spice medicinal and aromatic crops (PSMA) play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers and cater to the primary health care needs of a large section of people. This course will impart knowledge to the learner on the advanced breeding approaches followed in important PSMA crops in Indian perspectives.

V. Aim of the course

The course is designed to provide knowledge on modern approaches in the breeding of various PSMA crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Plantation crops	I Genetic resources II Breeding methods III Breeding achievements
2	Spice crops	I Genetic resources II Breeding methods III Breeding achievements
3	Medicinal and Aromatic crops	I Genetic resources II Breeding methods III Breeding achievements

VI. **Theory**

Block 1: Plantation Crops

Unit I: Genetic resources: Evolutionary mechanisms, adaptation and domestication, genetic resources, genetic divergence, cytogenetics, variations and natural selection, types of pollination and fertilization mechanisms, sterility and incompatibility systems in Plantation crops.

Unit II: Breeding methods: Introduction and selection, chimeras, clonal selections, intergeneric, interspecific and inter-varietal hybridization, heterosis breeding, mutation and polyploidy breeding, resistance breeding to biotic and abiotic stresses, breeding for improving quality, genetics of important traits and their inheritance pattern, molecular and transgenic approaches and other biotechnological tools in crop improvement.

Unit III: Breeding achievements: Breeding objectives, ideotype breeding, breeding problems and achievements in Plantation crops.

Block 2: Spice crops

Unit I: Genetic resources: Evolutionary mechanisms, adaptation and domestication, genetic resources, genetic divergence, cytogenetics, variations and natural selection, types of pollination and fertilization mechanisms, sterility and incompatibility systems in Spice crops.

Unit II: Breeding methods: Introduction and selection, chimeras, clonal selections, intergeneric, interspecific and intervarietal hybridization, heterosis breeding, mutation and polyploidy breeding, resistance breeding to biotic and abiotic stresses, breeding for improving quality, genetics of important traits and their inheritance pattern, molecular and transgenic approaches and other biotechnological tools in crop improvement.

Unit III: Breeding achievements: Breeding objectives, ideotype breeding, breeding problems and achievements in Spice crops.

Block 3: Medicinal and aromatic crops

Unit I: Genetic resources: Evolutionary mechanisms, adaptation and domestication, genetic resources, genetic divergence, cytogenetics, variations and natural selection, chemotaxonomy, pollination and fertilization mechanisms, sterility and incompatibility systems in Medicinal and Aromatic crops.

Unit II: Breeding methods: Introduction and selection, clonal selections, intergeneric, interspecific and intervarietal hybridization, heterosis breeding, mutation and polyploidy breeding, resistance breeding to biotic and abiotic stresses, breeding for improving quality, genetics of important traits and their inheritance pattern, genetic mechanisms associated with secondary metabolites, molecular and transgenic approaches and other biotechnological tools in crop improvement.

Unit III: Breeding achievements: Specific breeding objectives in medicinal and aromatic crops, ideotype breeding, breeding problems and achievements in medicinal and aromatic crops.

Crops

A. **Plantation crops:** Coconut, Arecanut, Oil palm, Cashew, Coffee, Tea, Cocoa, Rubber

B. **Spice crops:** Black pepper, Cardamom, Ginger, Turmeric, Nutmeg, Cinnamon, Clove, Garcinia, Coriander, Cumin, Fennel, Fenugreek, Ajwain, Dill.

C. **Medicinal crops:** Senna, Periwinkle, Aswagandha, Isabgol, Sarpagandha, Poppy, Glory lily, Medicinal coleus, *Mucuna pruriens*, Ocimum, *Centella asiatica*, *Bacopa monnieri*, *Andrographis paniculata*, *Aloe vera*, *Phyllanthus amarus*, Eucalyptus, Bael, Henbane.

D. **Aromatic crops:** Lemongrass, Palmarosa, Citronella, Vetiver, Mint, Sweet basil, Lavender, Geranium, Patchouli, Artemisia, Rosemary, Thyme, Sage, Marjoram, Fever few.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Presentation of review papers and research articles
- Exposure visits to research centres, PSMA crop based industries

VIII. Learning outcome

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

- be equipped with the latest research outcome in crop improvement of PSMA crops
- be able to start hi-tech PSMA crop based seed/ planting material production programmes

IX. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.
- Agarwal S, Divkarasastry EV and Sharma RK. 2001. *Seed Spices, Production, Quality and Export*. Pointer Publ.
- Anonymous. 1985. *Rubber and its Cultivation*. The Rubber Board of India.
- Atal C and Kapoor V. 1992. *Cultivation and Utilization of Medicinal and Aromatic Crops*.CSIR.
- Barche S. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi.
- Chadha KL. 2001. *Hand Book of Horticulture*. ICAR.

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I. **Course Title : Advanced Methods in Laboratory Techniques in PSMA Crops**

II. **Course Code : PSM 604**

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

IV. **Why this course ?**

Plantation, spice, medicinal and aromatic crops demand specific post harvest management and value addition. At each step it has to undergo quality assessment using modern equipment and machinery. Export standards are also based on stringent quality parameters. This course is designed to make the learner well versed with modern analytical methods, instruments and machinery used in quality analyses.

V. **Aim of the course**

To equip the students with the latest laboratory techniques required for assessing the quality of PSMA crops.

The course is organised as follows

No	Blocks	Units
1	Plantation Crops	I Physiological and biochemical changes Contaminants Value addition
2	Spice Crops	I Physiological and biochemical changes II Contaminants
III Value addition		
No	Blocks	Units
3	Medicinal and Aromatic Crops	I Secondary metabolites and their biosynthetic pathways Contaminants III Value addition

VI. **Theory**

Block 1: Plantation Crops

Unit I: Physiological and biochemical changes: Physiological and biochemical changes during maturity and ripening including post harvest changes. Factors influencing quality.

Unit II: Contaminants: Adulterants, substitutes, sources of contamination: microbial, heavy metal, pesticide residues.

Unit I: Physiological and biochemical changes: Physiological and biochemical changes during maturity and ripening including Post harvest changes. Factors influencing quality.

Unit II: Contaminants: Adulterants, substitutes, sources of contamination: microbial, heavy metal, pesticide residues.

Unit III: Value addition: Fixed oils, essential oils, value added products, grading,storage, transportation.

Block 3: Medicinal and aromatic crops

Unit I: Secondary metabolites and their biosynthetic pathways, factors affecting production of secondary metaboiltes, changes during maturity,harvesting and processing.

Unit II: Contaminants: Adulterants, substitutes, contamination: microbial, heavy metal, pesticide residues.

Unit III: Value addition: Fixed oils, essential oils, oleoresins, concretes, absolutes, dyes, natural colours, aroma chemicals, grading, storage, transportation. Quality standards of raw materials and finished products.

VII. **Practical**

- Sampling techniques in PSMA crops or their parts;
- Solvent extraction of spices and medicinal plants;
- Detection of adulterants and substitutes;
- Extraction of secondary metabolites from medicinal crops;
- Qualitative analyses of secondary metabolites;
- Quantitative estimation of secondary metabolites;
- Preparation of plant extracts;
- Chromatographic separation of extracts;
- Thin layer chromatography;
- Soxhlet extraction;
- Super critical fluid extraction;
- Determination of physical and chemical properties of essential oils;
- Flavor profile of essential oils by gas chromatography;
- Chemical characterization by HPTLC;
- Chemical characterization by GCMS;
- Chemical characterization by LCMS;
- Chemical characterization by NMR;
- Bioassay and High Throughput Screening;
- Techniques for assessment of antimicrobial property;
- Techniques for assessment of antioxidant property, pesticide residue analyses;
- Determination of heavy metals by flame photometry;
- Plant tissue cultures in the industrial production of bioactive plant metabolites;
- Exposure visit to leading medicinal and aromatic industries, accredited quality control labs.

VIII. **Learning outcome**

After completion of this course, the student will be equipped in

- the modern analytical methods of biochemistry
- handling of equipments and machinery used in biotechnology, processing and value addition

IX. **Suggested Reading**

- Barche S. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi.
- Das K. 2013. *Essential oils and their applications*. New India Publishing Agency, New Delhi. Hammon JM and Yusibov V. 2000. *Plant Biotechnology: New Products and application*. Springer-Verlag.
- Orhan I. 2012. *Biotechnological Production of Plant Secondary Metabolites*. Bentham Science Publishers.
- Raaman N. 2006. *Phytochemical techniques*. New India Publishing Agency, New Delhi. Ramawat KG. 2007. *Biotechnology: secondary metabolites: plants and microbes*. Science Publishers.
- Sadasivam S and Manickam A. 1991. *Biochemical methods*. New Age International Publishers.
- Shankar SJ. 2018. *Comprehensive post harvest technology of flowers, medicinal and aromatic plants*. Narendra Publishing House, New Delhi.
- Shukla Y.M. 2009. *Plant secondary metabolites*. New India Publishing Agency, New Delhi. Parimelzhagan T. 2013. *Turning plants into medicines: Novel approaches*. New India Publishing Agency, New Delhi.
- Tiwari C. 2018. *Antimicrobial properties of Medicinal plants*. Narendra Publishing House, New Delhi.
- Trivedi C. 2004. *Herbal drugs and biotechnology*. Pointer Publishers.
- Waghulkar VM. 2012. *Quality assurance techniques in pharmaceuticals.* New India Publishing Agency, New Delhi.

I. **Course Title : Biotechnological Approaches in PSMA Crops**

II. **Course Code : PSM 605**

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

IV. **Why this course ?**

Tools of biotechnology are widely used in crop improvement, crop management, crop protection and post harvest management of PSMA crops. This course is designed to impart knowledge on advanced biotechnological tools used in various spheres of plantation, spices, medicinal and aromatic crops.

V. Aim of the course

The main objective of the course is to impart to the learner, knowledge on advanced biotechnological tools used in various spheres of plantation, spices, medicinal and aromatic crops.

The course is organized as follows:

No	Blocks	Units
1	Plantation Crops	I *In-vitro* mass multiplication techniques II *In-vitro* breeding Transgenic crops
2	Spice Crops	I *In-vitro* mass multiplication techniques II *In-vitro* breeding III Transgenic crops
3	Medicinal and Aromatic multiplication techniques	I *In-vitro* mass Crops II *In-vitro* breeding III Transgenic crops IV *In-vitro* production of secondary metabolites

Theory

Block 1: Plantation Crops

Unit I: *In-vitro* mass multiplication techniques: *In-vitro* conservation of plantation crops, direct and indirect organogenesis, micro grafting, hardening techniques.

Unit II: *In-vitro* breeding: Production of haploids, somaclones and identification of somaclonal variants, *in-vitro* techniques to overcome fertilization barriers, protoplast culture and fusion, construction, identification and characterization of somatic hybrids and cybrids, wide hybridization, embryo rescue of recalcitrant species. *In-vitro* mutation for biotic and abiotic stresses, disease elimination in crops.

Unit III: Transgenic crops: Recombinant DNA methodology, gene transfer methods, tools, methods, applications of rDNA technology. Role of molecular markers in characterization of transgenic crops, fingerprinting of cultivars, etc., achievements, problems and future thrusts.

Block 2: Spice Crops

Unit I: *In-vitro* mass multiplication techniques: *In-vitro* conservation of spice crops. direct and indirect organogenesis, micro grafting, hardening techniques, production of microrhizomes.

Unit II: *In-vitro* breeding: Production of haploids, somaclones and identification of somaclonal variants, *in-vitro* techniques to overcome fertilization barriers, Protoplast culture and fusion, construction, identification and characterization of somatic hybrids and cybrids, wide hybridization, embryo rescue of recalcitrant species, *in-vitro* mutation for biotic and abiotic stresses, disease elimination in crops.

Unit III: Transgenic crops: Recombinant DNA methodology, gene transfer methods, tools, methods, applications of rDNA technology. Role of molecular markers in characterization of transgenic crops, fingerprinting of cultivars, etc., achievements, problems and future thrusts.

Block 3: Medicinal and Aromatic Crops

Unit I: *In-vitro* mass multiplication techniques: *In-vitro* conservation of medicinal and aromatic crops, direct and indirect organogenesis, micro grafting, hardening techniques, production of microrhizomes.

Unit II: *In-vitro* breeding: Production of haploids, somaclones and identification of somaclonal variants, *in-vitro* techniques to overcome fertilization barriers, Protoplast culture and fusion, construction, identification and characterization of somatic hybrids and cybrids, wide hybridization, embryo rescue of recalcitrant species, *in-vitro* mutation for biotic and abiotic stresses, disease elimination in crops.

Unit III: Transgenic crops: Recombinant DNA methodology, gene transfer methods, tools, methods, applications of rDNA technology. Role of molecular markers in characterization of transgenic crops, finger printing of cultivars, etc., achievements, problems and future thrusts.

Unit IV: *In-vitro* production of secondary metabolites: *In-vitro* production and characterization of secondary metabolites, bioreactors.

Crops

Coconut, Rubber, Oil palm, Coffee, Tea, Cocoa, Black pepper, Cardamom, Turmeric, Ginger, Vanilla, Periwinkle, Rauvolfia, Mint, Cymbopogon grasses, Medicinal coleus, *Ocimum* sp., Aswagandha, Aloe, Safed musli, Stevia

VI. Learning outcome

The learner is expected to be:

- acquainted with the applications of biotechnology in PSMA crops
- able to start modern labs based on biotechnology in PSMA crops

VII. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press. Bajaj YPS. Ed. 1987. *Biotechnology in Agriculture and Forestry*. Springer.
- Chadha KL, Ravindran PN and Sahijram L. Eds. 2000. Biotechnology of Horticulture and Plantation Crops. Malhotra Publ. House.
- Choudappa P, Anitha K, Rajesh MK and Ramesh SV. 2017. *Biotechnology of Plantation Crops*. Daya Publishing House, New Delhi.
- Choudappa P, Niral V, Jerard BA and Samsudeen K. 2017. *Coconut*. Daya Publishing House, New Delhi.
- Debnath M. 2005. *Tools and Techniques of Biotechnology*. Pointer Publ.
- *E-manual on Advances in Cashew Production Technology*. ICAR- Directorate of Cashew Research, Puttur –574 202, D.K., Karnataka.
- Glover MD. 1984. *Gene Cloning: The Mechanics of DNA Manipulation*. Chapman and Hall. Gorden H and Rubsell S. 1960. *Harmones and Cell Culture*. AB Book Publ.
- Keshavachandran R and Peter KV. 2008. *Plant Biotechnology: Tissue Culture and Gene Transfer*. Orient and Longman (Universal Press).
- Keshavachandran R, Nazim PA, Girija D and Peter KV. 2007. *Recent Trends in Biotechnology of Horticultural Crops*. New India Publ. Agency.
- Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.
- Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.
- 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 Prakash.
- Pierik RLM. 1987. *In-vitro Culture of Higher Plants*. MartinusNijhoff Publ.
- Pillay PNR. 1980. *Handbook of natural rubber production in India*. Rubber Research Institute, Kottayam. pp.668.
- Prasad S. 1999. *Impact of Plant Biotechnology on Horticulture*. 2nd Ed. AgroBotanica.

- Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
- Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology*. (Developments in Crop Science). Elsevier Science.
- Sharma R. 2000. *Plant Tissue Culture*. Campus Books, International.
- Shukla YM. 2009. *Plant secondary metabolites*. New India Publishing Agency, New Delhi. Singh BD. 2001. *Biotechnology*. Kalyani.
- Skoog F and Miller CO. 1957. *Chemical Regulation of Growth and Formation in Plant Tissue Culture in-vitro*. Symp. Soc. Exp. Biol. 11, 118-131.
- Williamson R. 1981-86. *Genetic Engineering*. Vols. I-V. Academic Press.

I. Course Title : Abiotic Stress Management in Plantation, Spice, Medicinal and Aromatic Crops

II. Course Code : PSM 606

III. Credit Hours : (2+1)

IV. Why this course ?

Global climate is undergoing drastic changes and crops find it difficult to adapt to the changed environments. Abiotic stress due to temperature, water, salts, radiations, nutrients, pollutants, etc. affects the growth, physiology, yield and quality attributes of PSMA crops. This course is designed for the learner to understand the influence of these abiotic stress factors on PSMA crops.

V. Aim of the course

The course aims to impart knowledge on the influence of abiotic stress factors on growth, physiology, yield and quality attributes of PSMA crops along with advanced approaches in the management of these stresses.

The course is organized as follows:

No	Blocks	Units
1	Abiotic Stress	I Temperature and water stress II Stress due to soil conditions and salt III Pollution stress IV Other stresses
2	Climate Change	I Contributing factors II Carbon trading III Impact of climate change on PSMA crops
3	Climate Resilient Technologies	I Varieties

VI. **Theory**

Block 1: Abiotic Stress

Definition, soil conditions (salinity, alkalinity, ion toxicity, fertilizer toxicity, etc.), salt stress

Unit I: Temperature and water stress: Stresses due to water (high and low), temperature (high and low), symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Unit II: Stress due to soil conditions and salts: Alkainity, salinity, iron toxicity, fertilizer toxicity symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Unit III: Pollution stress: Gaseous pollutants and heavy metals, symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Unit IV: Other stresses: Stress due to radiation, wind, nutrients. symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Block 2: Climate change

Unit I: Contributing factors: Introduction to climate change, factors contributing to climate change, change in temperature, rainfall, humidity, rise in the atmospheric CO_2 levels, tropospheric ozone levels, extreme climatic events.

Unit II: Carbon trading: Global warming, carbon trading, role of green housegases, impact on productivity of PSMA crops. Clean development mechanism.

Unit III: Impact of climate change on PSMA crops: Plantation crops, Spice crops, Medicinal and aromatic crops.

Block 3: Climate resilient technologies

Unit I: Varieties: Plantation crops, Spice crops, Medicinal and aromatic crops.

Unit II: Climate resilient technologies: Plantation crops, Spice crops, Medicinal and aromatic crops.

Unit III: Waste management: Alternate farming systems, Zero waste management, Microbial waste management.

VII. Practical

- Analysis of plant stress factors;
- Relative water content;
- Chlorophyll stability index;
- Plant waxes;
- Stomatal diffusive resistance;
- Transpiration;
- Photosynthetic rates;
- Calculation of water use efficiency and growth rates;
- Identifying abiotic stress symptoms and injuries;
- Use of antitranspirants;
- Managing nutrient stress;
- Stress management by hormones;
- Screening for abiotic stress tolerance;
- Weather data analyses and quantification of climate change;
- Cropping pattern changes due to climate extremities;
- Phenological and quality changes in PSMAs;
- Pesticide residue analysis in PSMAs.

VIII. Learning outcome

The learner is expected to get empowered on

- the impact of abiotic stress on PSMA crop production
- the mitigation measures to be adopted for sustaining PSMA crop production

IX. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.
- Ahmad, Parvaiz, and Prasad MNV. 2012. *Abiotic Stress Responses in Plants Metabolism, Productivity and Sustainability*. Springer.
- E- manual on *Advances in Cashew Production Technology*. ICAR-Directorate of Cashew Research, Puttur– 574 202, D.K., Karnataka.
- Prasad HC, Rao, Sriniv NK, Shivashankar and Seetharamaiah K. 2013. *Climate-Resilient Horticulture: Adaptation and Mitigation Strategies*. Springer.
- Hebbar KB, Kumar SN and Choudappa P. 2017. *Impact of climate change on Plantation Crops*. Daya Publishing House, New Delhi.
- Jenks MA and Hasegawa PM. 2003. *Plant Abiotic Stress*. Black Well.
- Levitt J. 1972. *Response of Plants to Environmental Stresses*. Academic Press.
- Manish B. 2018. *Climate resilient agriculture: Adaptation, mitigation strategies*. New India Publishing Agency, New Delhi.
- Mussell H and Staples R. 1979. *Stress Physiology in Crop Plants*.

Wiley Inter. Science. Nickell LG. 1983. *Plant Growth Regulating Chemicals*. CRC Press.

- Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.
- Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.
- Pillay PNR. 1980. *Handbook of natural rubber production in India*. Rubber Research Institute, Kottayam. pp.668.
- Rao Prasada GSHLV, Rao, GGSN and Rao, VUM. 2008. *Climate Change and Agriculture over India*. Kerala Agricultural University, Thrissur.
- Roy B and AK Basu. 2009. *Abiotic stress tolerance in crop plants*. New India Publ. House. Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
- Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science*). Elsevier Science.
- Shanker AK and Venkateswarlu B. 2011. *Abiotic Stress in Plants– Mechanisms and Adaptations*. In tech, Croatia.
- Turner NC and Kramer PJ. 1980. *Adaptation of Plants to Water and High Temperature Stress*. John Wiley and Sons.
- Venkateswarlu B, Shanker AK, Chitra M and Maheswari M. *Crop Stress and its Management: Perspectives and Strategies*. Springer.
- www.plantphysiol.org, www.plantsress.com

I. Course Title : Organic Spice and Plantation Crops Production

II. Course Code : PSM 607

III. Credit Hours : (2+1)

IV. Why this course ?

A shift to organic agriculture is happening in different parts of the world. Demand for organic plantation and spice crops is also increasing globally. This course is designed to give comprehensive knowledge on scientific organic farming technologyin plantation and spice crops.

V. Aim of the course

To impart knowledge on principles, concepts, techniques and certification proceduresof organic farming in spice and plantation crops

The course is organized as follows

No	Blocks	Units

1	Concepts of Organic Farming	I. Importance II. Organic conversion plan III. Organic farming systems
2	Organic Production Technologies	I. Plantation crops II. Major spices III. Minor spices
3	Certification and Quality Control	I. Accreditation II. Organic standards III. Quality control

VI. Theory

Block 1: Concepts of Organic Farming

Unit I: Importance: Principles, perspectives, concepts and components of organic farming, present status of organic farming at national and global level, domestic and global demand for organic products with respect to spice and plantation crops, organic production and export– opportunities and challenges.

Unit II: Organic Conversion Plan: Advanced methods for enhancing soil fertility, soil amendments. Modern methods of composting, vermicomposting, coir pith composting, bio fertilizers, pest and disease management in organic farming; crop rotation in organic horticulture, weed management, botanicals and bio- control agents.

Unit III: Organic Farming Systems: Natural farming, permaculture, biodynamic farming, Zero budget farming, Homa farming, EM technology.

Block 2: Organic Production Technology

Unit I: Plantation crops: Coconut, Coffee, Cocoa, Tea.

Unit II: Major Spices: Black pepper, Cardamom, Ginger, Turmeric, Vanilla.

Unit III: Seed spices: Coriander, Cumin, Fennel, Fenugreek.

Block 3: Certification and Quality Control

Unit I: Accreditation: Accreditation agencies, certification agencies, procedure of certification, types of certification.

Unit II: Organic standards: Domestic and international standards, NPOP, IFOAM, CODEX, HACCP standards.

Unit III: Quality control: Participatory Guarantee System (PGS) in quality control, quality control for organic products.

VII. Practical

- Enrichment of composts;

- Biofertilizers;
- Bio control agents;
- Biodynamic preparations;
- Zero- budget preparations;
- Biopesticides;
- AMF in organic production;
- Waste management techniques;
- Exposure visits to organic fields, certification and marketing centers.

VIII. Learning outcome

The learner is expected to get empowered on

- the organic farming techniques in Spice and Plantation crops
- the organic certification procedures in Spice and Plantation crops

IX. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press. Dahama AK. 2005. *Organic Farming for Sustainable Agriculture*. 2nd Ed. Agrobios.
- E- manual on *Advances in Cashew Production Technology*. ICAR-Directorate of Cashew Research, Puttur –574 202, D.K., Karnataka.
- Gehlot G. 2005. *Organic Farming: Standards, Accreditation, Certification and Inspection*. Agrobios.
- Palaniappan SP and Annadarai K. 2003. *Organic Farming: Theory and Practice*. Scientific Publ.
- Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.
- Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.
- Parthasarthy VA, Kandiannan V and Srinivasan V. 2008. *Organic Spices. New India* Publ. Agency.
- Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2008. *Management of Horticultural Crops*. New India Publ. Agency.
- Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
- Shivashankar K. 1997. *Food Security in Harmony with Nature*. 3, IFOAM-RD, ASIA, Scientific Conference. 1-4 Dec., 1997, UAS, Bangalore.

I. Course Title : Marketing and Trade of Plantation, Spices,

Medicinaland Aromatic Crops

II. **Course Code : PSM 608**

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

IV. **Why this course ?**

Marketing and trade are two important aspects in the domestic as well as international movement of PSMA crops. Instability in the price structure as well as demand of various plantation and spice crops often puts the farmers and entrepreneurs at risk. This course is designed to impart in the learner a deeper understanding on marketing and trade in raw materials and value added products of PSMAs crops both at the domestic and international level.

V. **Aim of the course**

This course is designed to impart in the learner a deeper understanding on marketing and trade in raw materials and value added products of PSMAs crops both at the domestic and international level.

The course is organized as follows

No	Blocks	Units
.	Market opportunities	Importance of Marketing and T e
	II. Marketing strategies	
2	Marketing Channels	I. Market organisations II. Value chain management and total quality management
3	Entrepreneurship Development	I. Decision making II. Price structure

VI. **Theory**

Block 1: Importance of marketing and trade

Unit I: Market opportunities: Market opportunities and challenges in PSMA crops at the domestic and global level, consumption in India’s plantation, herbal and spice and other industries, Demand-supply scenario of PSMAs at the national and international level, Marketing and trade in raw materials and value added products

Unit II: Marketing strategies: Direct and indirect marketing, niche marketing, specialty markets, market intermediaries and their role, market infrastructure needs, marketing efficiency. market organization, planning, promotion, cost control, contract farming

Block 2: Marketing Channels

Unit I: Market organizations: Marketing co-operatives including tribal co- operatives, public private partnerships (PPP), Farmer Producer Companies (FPC) and Farmer Producer Organisations (FPOs).

Unit II: Supply chain management and total quality management: Good transportation procedures, cold storage facilities, State trading, warehousing and other govt. agencies. Role of commodity boards and export promotion councils in marketing and export of PSMA crops

Block 3: Entrepreneurship development

Unit I: Decision making: Risk taking, motivation, importance of planning, monitoring, evaluation and follow up, SWOT analysis, generation, incubation and commercialisation of ideas and innovations. Communication skills, domestic and export market intelligence, export standards. Role of information technology and telecommunication in marketing of PSMAs

Unit II: Price structure: Price analysis and price forecasting in PSMA crops, policies on export, import and re-export of commodities and value added products, guidelines for marketing of organic produce and organic products

VI. Practica

- Study of requirement of various raw materials by the plantation, spice and ayurveda industries;
- Demand supply analysis of various PSMA crops;
- Exposure visit to trading centres, exporters, ware houses, value addition units, etc.;
- Study of FPOs and FPCs in various crops;
- Preparation and evaluation of projects;
- Documentation of case studies.

VII. Learning outcome

The learner is expected to get empowered on

- the marketing and trade opportunities and channels in PSMA crops
- the entrepreneurship development and value chain in PSMA crops
- decision support and pricing system in PSMA crops

VIII. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC

Press.

- Chinnappa B. 2018. *Economics and marketing of Arecanut in India*. Narendra Publishing House, New Delhi.
- CUTS. 2004. *Data base on Medicinal Plants*. CUTS Centre for International Trade, Economics and Environment, Calcutta.
- E-manual on *Advances in Cashew Production Technology*. ICAR-Directorate of Cashew Research, Puttur-574 202, D.K., Karnataka.
- Holly J and Cheria K. 1998. *The medicinal plant Sector in India*. Medicinal and Aromatic Programme in Asia (MAPPA), New Delhi, India.
- Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.
- Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.
- Pillay PNR. 1980. *Handbook of natural rubber production in India*. Rubber Research Institute, Kottayam. pp.668.
- Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
- Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.
- Tyagi SK. 2015. *Spices, Plantation Crops, Medicinal and Aromatic plants-a hand book.* New India Publishing Agency.
- Varmudi. 2001. *Marketing of Spices*. Daya publishing house.
- Ved DK and Goraya GS. 2007. *Demand and Supply of Medicinal Plants in India*. NMPB, New Delhi, FRLHT, Bangalore.

e-Resource

www.nmpb.nic.in

Suggested Journals

Sr. No.	Name of the Journal	ISSN No.
1	*Annals of Horticulture*	0976-4623
2	*Biological Agriculture and Horticulture*	2165-0616
3	*Current Horticulture*	2455-7560
4	*European Journal of Medicinal Plants*	2231-0894
5	*Horticulture Enviornment and Biotechnology*	2211-3460

6	*Indian Coconut Journal*	0970-0579
7	*Indian Horticulture Journal*	2347-3029
8	*Indian Journal of Arecaunt Spices and Medicinal Plant*	0972-2483
9	*Indian Journal of Arid Horticulture*	2249-5258
10	*Indian Journal of Horticulture*	0974-0112
11	*International Journal of Horticulture*	1927-5803
12	*International Journal of Horticulture, Agriculture and Plant Sciences*	2572-3154
13	*International Journal of Innovative Horticulture*	2320-0286
14	*International Journal of Seed Spices*	
15	*International Journal of Tea Science*	0972-544X
16	*Journal of Applied Horticulture*	0972-1045
17	*Journal of Herbs, Spices, and Medicinal Plants*	1540-3580
18	*Journal of Medicinal and Aromatic Plant Sciences*	0253-7125
19	*Journal of Medicinal Food*	1557-7600
20	*Journal of Medicinal Plant Research*	1996-0875
21	*Journal of Medicinal Plant Studies*	2320-3862
22	*Journal of Plantation Crops*	2454-8480
23	*Journal of Spices and Aromatic Crops*	0971-3328
24	*Medicinal Plants: International Journal of Phytomedicines and Related*	0975-4261
25	*Polycyclic Aromatic Compounds*	1040-6638
26	*Progressive Horticulture*	2249-5258
27	*Rubber Science (Natural Rubber Research)*	2524-3993
28	*Spice India*	0970-5805
29	*The Asian Journal of Horticulture*	0973-4767

POSTHARVEST MANAGEMENT

Course Title with Credit Load for M.Sc. (Hort.) in Post-Harvest Management

Course Code	Course Title	Credit Hours
PHM 501 *	Postharvest Management of Horticultural Produce	2+1
PHM 502*	Postharvest Physiology and Biochemistry of Perishables	2+1
PHM 503	Packaging and Storage of Fresh Horticultural Produce	1+1
PHM 504	Packaging and Storage of Processed Horticultural Produce	1+1
PHM 505*	Principles and Methods of Fruit and Vegetable Preservation	2+1
PHM 506	Laboratory Techniques in Postharvest Management	1+2
PHM 507*	Processing of Horticultural Produce	2+2
PHM 508	Quality Assurance, Safety and Sensory Evaluation of Fresh and Processed Horticultural Produce	2+1
PHM 509	Functional Foods from Horticultural Produce	2+0
PHM 510	Marketing and Entrepreneurship in Postharvest Horticulture	1+1
PHM 511	Value addition and processing of planation crops and spices	2+1
PHM 512	Value addition of medicinal and aromatic plants	2+0
	Minor Courses (08 credits)	08
	Supporting Courses (06 credits)	06
	Common compulsory courses (05 credits)	05
PHM 591	Seminar	0+1
PHM 599	Research	0+30
	Total	**70**

*Compulsory among major courses

Course Title : **Postharvest Management of Horticultural Produce**

Course Code : **PHM 501**

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

Why this course ?

Fruits and vegetables are perishable crops that suffer great losses both in quantity and quality after harvest. These produce require integrated approach to arrest their spoilage and overcome the present day challenges that assimilates millions of tons annually. Lack of postharvest awareness and absence of sufficient and functioning equipment in the postharvest chain result in serious postharvest losses in developing countries. Clear and comprehensive understanding of postharvest deteriorative factors is necessary to overcome these challenges. Pre and postharvest management such as good cultural practices, use of improved varieties, good handling practices pre and postharvest, temperature and relative humidity management, storage atmosphere management, use of permitted chemicals, design of appropriate packaging materials and storage structures are some of the control measures use in reducing postharvest losses. Hence this customized course

Aim of the course

To impart comprehensive knowledge on management of horticultural produce thus extending the post-harvest life of the produce by various treatments.

The course is organized as follows:

No.	Block	Unit
1.	Post harvest management of horticultural produce	I. Importance and scope II. Regulation of ripening III. Treatment for extending shelf life IV. Handling system and marketing of horticultural crops

Theory

Block 1: Postharvest Management of Horticultural Produce

Unit I: History, Importance and scope of Postharvest technology of horticultural produce. Nature and structure of horticultural produce. Pre and Postharvest losses and their causes.

Unit II: Climacteric and non-climacteric fruits. Regulation of ripening by use of chemicals and growth regulators. Control of sprouting, rooting and discoloration in vegetables.

Unit III: Maturity indices for harvest. Harvesting and harvesting tools. Curing in roots and tubers. Prepackage Operation: Preecooling, washing, sorting, grading of horticultural perishables for local markets and export. Postharvest handling of spices, plantation crops, medicinal and aromatic plants. Equipments for washing, sizing, grading.

Unit IV: Pre and Postharvest treatments for extending storage life/ vase life. VHT, irradiation treatment, skin coating, degreening, etc. Prepackaging, Packaging techniques for local market and Standards and specifications for fresh produce export

Unit V: Postharvest handling system for horticulture crops of regional importance. Principles of transport, modes of transportation, types of vehicles and transit requirements for different horticultural produce. Marketing: Factors influencing marketing of perishable crops, marketing systems and organizations.

Practical

- Study of maturity indices for harvest of fruits, vegetables, spices and plantation crops;
- Protective skin coating with wax emulsion and pre and Postharvest treatment with fungicides, chemicals and growth regulators to extend the shelf life of fruits and vegetables;
- Prepackaging of perishables;
- Extension of vase life of cut flowers by use of chemicals and growth regulators;
- Control of sprouting of potato and onion by using growth regulators;
- Study of modern harvesting, sorting and grading equipments;
- Study of effect of pre-cooling on shelf-life and quality of fresh fruits, vegetables and flowers;
- Visit to packaging centers;
- Visit to local markets, cooperative organizations, super markets dealing with marketing of Perishables.

Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentation
- Group Work/ seminars

Learning outcome

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

- Regulation of ripening by use of chemicals and growth regulators
- Pre and Postharvest treatments for extending storage life/ vase life
- Standards and specifications for fresh produce

Suggested Reading

- Bhattacharjee SK and Dee LC. 2005. *Postharvest technology of flowers and* *ornamental plants*. Pointer publishers, Jaipur.

- Chattopadhyay SK. 2007. *Handling, transportation and storage of fruit and vegetables*. Gene- Tech books, New Delhi.
- FAO. 2007. *Handing and Preservation of Fruits and Vegetables by Combined methods for Rural Areas*-Technical Manual. FAO Agr.Ser.Bull., 149.
- Kader AA. 1992. *Postharvest technology of horticultural crops*. 2nd ed university of California. Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Postharvest Biology and Technology of Fruits, Vegetables and Flowers*, Wiley-Blackwell, ISBN: 9780813804088.
- Pruthi JS. 2001 (Reprint). *Major spices of India crop management and Postharvest technology*. ICAR, NewDelhi
- Stawley J Kays. 1998. *Postharvest physiology of perishable plant products*. CBS publishers. Sudheer KP, Indira V. 2007. *Postharvest Technology of Horticultural Crops*, Peter K.V. (Ed.), New India Publishing Agency, ISBN 9788189422431.
- Sunil Pareek (Ed.) 2016. *Postharvest Ripening Physiology of Crops*, CRC Press, ISBN 9781498703802.
- Thompson AK. (Ed.) 2014. *Fruit and Vegetables: Harvesting, Handling and Storage* (Vol. 1 & 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.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.

Websites:

Horticulture-Post harvest management CSIR-NISTADS
http://www.nistads.res.in/indiasnt2008/ t6rural/t6rur13.htm
Post harvest technology- MANAGE http://www.manage.gov.in/ftf-itt/prgReports/iihr.pdf Role of post-harvest management
http://www.fao.org/3/y5431e/y5431e02.htm

Course Code	**:**	**PHM502**
Course Title	**:**	**Postharvest Physiology and Biochemistry of Perishables**
Credit Hours	**:**	**(2+1)**

Why this course?

Immediately after harvesting, vegetables and fruits are subjected to the active processes of degradation. Numerous physiological and biochemical processes continuously change the original composition of the crop until which decrease the shelf life of the produce. Postharvest physiology is the scientific study of the physiology of living plant tissues after picking. It is very much necessary to learn about it as has direct applications to postharvest handling in establishing the storage and transport conditions that prolong shelf life. Hence this customized course.

Aim of the course

To impart comprehensive knowledge on physiology of horticultural produce after harvest and to understand different physiological processes like respiration ripening

The course is organized as follows:

No	Blocks	Units
1	Biochemistry of perishable	I Structure and composition of horticultural produce II Biochemical Changes after harvest
2	Postharvest physiology of perishables	I Maturity, Ripening and respiration II Respiratory climacteric and transpiration III Factors affecting shelf-life

Theory

Block 1: Biochemistry of perishables

Unit I: Introduction, biochemical structure and composition of fruits, vegetables and ornamentals.

Unit II: Biochemical changes during development and ripening. Structural Deterioration of the Produce-cell wall degradation, change in membrane lipid.: Biosynthesis of ethylene and its regulation. Ethylene action and ripening processes, its perception-action and regulation.

Block 2: Postharvest physiology of perishables

Unit I: Determining maturity and maturity indices. Ripening processes: events of ripening and factors affecting them.

Unit II: Physiology of preharvest and postharvest; factors affecting shelf-life and quality of fruits, vegetables and ornamentals.

Unit III: Respiration: respiratory climacteric, its significance. Transpiration and water stress during postharvest. Postharvest oxidative stress: active oxygen species, AOS generation, physiological effects on horticultural commodity, control of oxidative injury.

Practical

- Determination of physical parameters like specific gravity, fruit firmness, etc.;

- Determination of physiological loss in weight;
- Determination of chemical constituents like sugar, starch, pigments, Vitamin C, acidity during maturation and ripening in fruits/ vegetables;
- Estimation of ethylene evolved from ripening fruits;
- Delay/ Hastening of ripening by ethylene treatments;
- Determination of firmness, TSS, moisture, Titratable acid, sugar, protein, starch, fats, chlorophyll, carotene, anthocyanin, phenols and tannins;
- Measurement of respiration and ethylene evaluation.

Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations
- Group Work

Learning outcome

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

- Understand about different factors affecting shelf life
- Processes of respiration and ripening
- Biosynthesis of ethylene and its action on ripening

Suggested Reading

- Chadha KL and Pal RK. 2015. *Managing postharvest quality and losses in horticultural crops*. Vol-1: General Issues, 1-231p Astral International (P) Ltd., New Delhi
- Chadha KL and Pal RK. 2015. *Managing postharvest quality and losses in horticultural crops*. Vol-2: Fruit Crops, 253-561p Astral International (P) Ltd., New Delhi
- Chadha KL and Pal RK. (2015) *Managing postharvest quality and losses in horticultural crops*. Vol-3: Vegetables, Flowers and Plantation Crops, 581-727p Astral International (P) Ltd., New Delhi
- Hodges DM. 2003. *Postharvest Oxidative Stress in Horticultural Crops*, 1st Edition, ISBN 9781560229636
- Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Postharvest Biology and Technology of Fruits, Vegetables and Flowers*, Wiley-Blackwell, ISBN: 9780813804088.
- Sunil Pareek (Ed.) 2016. *Postharvest Ripening Physiology of Crops*,CRC Press, ISBN 9781498703802.
- Thompson AK. 1995. *Post harvest Technology of fruits and vegetables*. Blackwell Sciences 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.

- Wills RBH and Golding J. 2017. *Advances in Postharvest Fruit and Vegetable Technology*, CRC Press, ISBN 9781138894051.
- Wills RBH and Golding J. 2016. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*, CABI Publishing, ISBN 9781786391483.
- **Websites**
- Food and Agriculture Organization http://www.fao.org/home/en/ Respiration in plants http://ncert.nic.in/ncerts/l/kebo114.pdf
- Ethylene biosynthesis and its response http://www.biologydiscussion.com/ plants/hormones - plants / ethylene-biosynthesis- and-its-responses-plant-hormones/25986

Course Title : Packaging and Storage of Fresh Horticultural Produce

Course Code : PHM 503

Credit Hours : (1+1)

Why this course ?

Being a potential source of minerals, vitamins and proteins and carbohydrates, horticultural commodities play an important role in the health and nutritional security of the people. Proper packaging and storage will utilize market surplus during glut season and thus give boost to the food industry. Horticultural produce is highly perishable particularly under tropical conditions of India. The spoilage of these commodities can be reduced to a large extent by this storage technology. Hence this customized course

I. Aim of the course

To acquaint with the different storage systems and packaging systems for perishable horticultural produce.

The course is organized as follows:

No	Blocks	Units
1	Storage systems	I. Importance of storage II. Different methods of storage III. Modified methods of storage
2	Packaging	I. Importance of packaging and packaging methods II. New technologies in packaging

II. **Theory**

Block 1: Storage Systems

Unit I: Importance of storage of horticultural produce, present status and future scope. Principles and methods of storage – field storage structures and designs for bulk storage of horticultural produce- onion and potato, etc. Evaporative cool chambers. Physiological changes during storage.

Unit II: Refrigerated storage – principles of refrigeration, types of refrigerants, refrigeration equipments. Cold storage rooms – Calculation of refrigeration load. Storage requirements of different fruits, vegetables, flowers. Storage disorder symptoms and control.

Unit III: Controlled or modified atmosphere (CA/MA) storage – principles, uses, structures and equipments, methods and requirements. Effect of CA storage on the physiology of stored produce. Hypobaric storage- principle, uses, and requirements. Storage disorders.

Block 2: Packaging

Unit I: Importance of packaging of fresh and processed horticultural produce, present status and future scope. Gaps in packaging concepts. Packaging requirements of fresh horticultural produce. Packaging patterns and methods. Food packaging systems: Different forms of packaging such as rigid, semi-rigid, flexible forms. Traditional, improved and specialized packages. Paper based packages: corrugated fibre board boxes – raw material and types of boxes. Flexible packaging materials – types and their properties. Consumer and intermediate flexible bulk containers. Testing of flexible packaging material. Barrier properties of packaging materials.

Unit 2: New technology in packaging – stretch wrapping system, vacuum packaging, gas packaging, controlled atmosphere (active and intelligent) packaging, vibra packaging, skin packaging, shrink packaging, form- fill-seal packaging, Packaging machines. Quality control and safety aspects of packaging materials.

III. **Practical**

- Study of special storage structures for bulk storage of onion/ potato, etc.;
- Study of storage behavior of different fruits and vegetables in zero energy cool chamber;
- Determination of refrigeration requirements (capacity) for given quantity of fruits and vegetables;
- Study of storage behaviour of different fruits and vegetables in cold room;

- Study of chilling injury and storage disorders;
- Study of shelf-life of fruits and vegetables in modified atmosphere packaging. Visit to special storage structures, cold storage units. Study of types of packaging materials, types of plastic films and their properties;
- Determination of water vapour transmission rate (WVTR) and gas transmissionrate (GTR) of packaging material;
- Applications of packaging material for fresh fruits and vegetables, beverages, spice products;
- Determination of shelf-life of fresh products in different types of packages;
- Study of packaging machines – vacuum packaging machine, shrink wrappingmachine, double seamer, etc. Visit to packaging unit.

IV. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations
- Group work/ seminars

V. Learning outcome

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

- Importance of storage of horticultural produce
- Different methods of storage
- Importance of packaging for fresh horticultural produce
- Different methods of packaging

VI. Suggested Reading

- Ahvenainen R. 2003. Novel Food Packaging Techniques, CRC Press, ISBN 0849317894. Ahvenainen R. 2001. *Novel Food Packaging Techniques*. CRC.
- Burg SP (Ed.). 2004. *Postharvest physiology and hypobaric storage of fresh produce*, CABI Publishing, ISBN 0851998011.
- Chattopadhya SK. 2007. *Handling, transportation and storage of fruits and vegetables*. Gene- Tech books, New Delhi.
- Chandra GopalaRao. 2015. *Engineering for Storage of Fruits and Vegetables*; Academic Press, 1st Edition.
- Coles R, McDowell D and Kirwan MJ. (Eds.). 2003. *Food Packaging Technology*, Blackwell Publishing, ISBN 1841272213.
- Mahadevaiah M and Gowramma RV. 1996. *Food packaging*

materials. Tata McGraw Hill. Painy FA. 1992. *A handbook of food packaging*. Blackie Academic.

- Pantastico B. 1975. Postharvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables. AVI Publ.Robertson GL. (Ed.). 2010. Food packaging and shelf life: a practical guide CRC Press, ISBN 9781420078442.
- Thompson AK. 2010. *Controlled atmosphere storage of fruits and vegetables* (2nd Edition), CABI International, ISBN 9781845936464.
- Wilson CL. (Ed.). 2007. *Intelligent and active packaging for fruits and vegetables*, CRC Press, ISBN 9780849391668.

Websites

- Storage practices and structures UCANR http://ucanr.edu/datastoreFiles/234-1303.pdf
- Low cost storage technologies for preservation-IARI http://www.iari.res.in/download/pdf/ story4_eng.pdf
- https://energypedia.info/wiki/Cold_Storage_of_Agricultural_Products

Course Code : PHM 504

Course Title : Packaging of Processed Horticultural Produce

Credit Hours : (1+1)

I. Why this course ?

Horticulture industry is dominated by market interaction in terms processing and their packaging. Much of the total cost of produce is determined by nature of packaging and packaging material used. Packaging cost sometimes exceed the raw material cost, depending on the nature of the produce, time and period. This course helps in understanding the packaging interaction with produce, environment and time. And it also helps to take informed decision on package requirement for horticulture produce.

II. Aim of the course

To acquaint with the different and packaging systems for processed horticultural produce.

The course is organized as follows:

No	Blocks	Units
1	Packaging principles and functions	Functions of packaging Basic principles of packaging materials Manufacture of packaging materials Types of packaging materials, Testing of packaging

III. Theory

Block 1: Packaging principles and functions

Unit I: Functions of packaging; Type of packaging materials; Selection of packaging material for different foods; Selective properties of packaging film; Methods of packaging and packaging equipment.

Unit II: Mechanical strength of different packaging materials; Printing of packages; Barcodes and other marking; Interactions between packaging material and foods; Environmental and cost consideration in selecting packaging materials.

Unit III: Manufacture of packaging materials; Potential of biocomposite materials for food packaging; Packaging regulations; Packaging and food preservation; Disposal of packaging materials.

Unit IV: Metal cans: types, fabrication, lacquering and tin quality. Double seaming technology – defects and causes. Glass containers – types; testing quality – thermal shock resistance, thermal shock breakage, impact breakage.

Unit V: Testing of packaging; Rigid and semi rigid containers; containers; Sealing Flexible Equipment. Labeling; Aseptic and shrink packaging; Secondary and transport packaging. Different packaging systems for dehydrated foods, frozen foods, dairy foods, fresh fruits and vegetables.

IV. Practical

- Testing of packaging material: compression strength/drop test/thermal shock test/seam evaluation/ seam defects;
- Determination of shelf-life of processed products in different types of packages;
- Study of packaging machines – vacuum packaging machine, shrink wrapping machine, double seamer, etc.;
- Visit to packaging units.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations
- Group Discussions

IX. Learning outcome

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

- Importance of packaging for processed horticultural produce
- Different methods of packaging, methods and their applications in food industry.

X. **Suggested Reading**

- Ahvenainen R. 2001. *Novel Food Packaging Techniques*. CRC
- Ahvenainen R. 2003. *Novel Food Packaging Techniques*, CRC Press, ISBN 0849317894. Coles R, McDowell D and Kirwan MJ. (Eds.) 2003. *Food Packaging Technology*, Blackwell Publishing, ISBN 1841272213.
- Joseph H Hotchkiss. 1987. *Food and Packaging Interactions*, (ACS symposium series -365, April 5-10, 1987. American Chemical Society, Washington DC. 1988)
- Mahadevaiah M and Gowramma RV. 1996. *Food packaging materials*. Tata McGraw Hill. Painy FA. 1992. A handbook of food packaging. Blackie Academic.
- Robertson G. L. Ed. 2010. *Food packaging and shelf life: a practical guide CRC Press*, ISBN 9781420078442.
- Thompson AK. 2010. *Controlled Atmosphere Storage of Fruits and Vegetables*, CABI Publishing; 2nd revised edition.
- Wilson CL. (Ed.). 2007. *Intelligent and active packaging for fruits and vegetables*, CRC Press, ISBN 9780849391668.

Course Code : PHM 505

Course Title : Principles and Methods of Fruit and Vegetable Preservation

Credit Hours : (2+1)

I. **Why this course ?**

The fruits and vegetables are comparative higher value than cereals and more perishables. Losses in the fruits and vegetables are high and chances to reduce the waste and enhancing the employability through post-harvest processing are more. The processing includes pre-processing of fruits and vegetables before these are fit to final conversation into processed foods. The food preservation and processing industry has now become of a necessity than being a luxury. It has an important role in conservation and better utilization of fruits and vegetables. In order to avoid the glut and utilize the surplus during the season, it is necessary to employ modern methods to extend storage life for better distribution and also processing techniques to preserve them for utilization in the off season on both large scale and small scale. Hence this customized course.

II. **Aim of the course**

Understanding spoilage, underlying principles and methods of processing of fruits and vegetables.

III. **Learning outcome**

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

- Understand Principles and different methods of preservation
- Principal spoilage organisms, food poisoning and their control

measures

- Canning of fruits and vegetables
- Processing equipments and layout of processing industry

IV. **Theory**

Block 1: Principles and Methods of Fruit and Vegetable Processing

Unit I: Introduction, Historical development in food processing, type of food and causes for food spoilage. Basic principles of fruits and vegetables processing;

Unit II: Thermal processing, pH classification of foods, heat resistance of microorganism; Heat resistance of enzymes in foods, Spoilage of thermal processed food; Containers – canning, rigid tin plates

and cans, aluminium cans, glass containers – types; flexible packaging materials, Composite can, specification, corrosion of cans, heat penetration into containers and methods for determination of process time.

Unit III: Effects of low temperature on fresh commodities and prepared product. Freezing preservation, freezing points of foods, slow and quick freezing, Cryogenic freezing and frozen food storage. Drying and dehydration, sun drying solar dehydration, mechanical drying types of driers, osmotic dehydration.

Unit IV: Food fermentation – alcoholic, acetic and lactic fermentation. Pickling and curing; Effect of salt on food preservation, types of salt cured products. Traditional and new products; chemical preservation, SO_2, benzoic acid, sorbic acid, antioxidants and antibiotics, newer preservatives. Preservation by controlling water activity – high sugar products, intermediate moisture food, food concentration.

Unit V: Food irradiation, principles, types and sources of radiation, mode of action of ionizing radiation; radiation effect on food constituents and regulation.

VII. **Practical**

- List and cost of equipment, utensils, and additives required for small scale processing industry;
- Chemical analysis for nutritive value of fresh and processed fruits and vegetables;
- Preparation and preservation of fruit based beverages and blended products from fruits and vegetables;
- Evaluation of pectin grade; preparation and quality evaluation of fruit jam;
- Preparation of papain;
- Blanching and its effects on enzyme;
- Preparation of dehydrated vegetables;

- Study of different types of spoilages in fresh as well as processed horticultural produce;
- Study of biochemical changes and enzymes associated with spoilage;
- Sensory evaluation of fresh and processed fruits and vegetables;
- Visit to processing units.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Exposure visits
- Student presentation
- Group Work

IX. Suggested Reading

- Barret DM, Somogyi LP and Ramaswamy H. Eds. 2005. *Processing Fruits: Science and Technology* (2nd Edition), CRC Press, ISBN 9780849314780.
- FAO. 2007. *Handling and Preservation of Fruits and Vegetables by Combined Methods for Rural Areas- Technical Manual*. FAO Agricultural Services Bulletin 149.
- Fellows PJ. 2009. Food Processing Technology: Principles and Practice (3rd Edition), Woodhead Publishing, ISBN 9781845692162.
- Lal G, Siddappa GS and Tandon GL. 1998. Preservation of Fruits and Vegetables. ICAR, ISBN 9788171640904.
- Ramaswamy H and Marcotte M. 2006. *Food Processing: Principles and Applications*. Taylor & Francis.
- Salunkhe DK and Kadam SS. 1995. Handbook of Fruit Science and Technology:Production, Composition and Processing. Marcel Dekker.
- Srivastava RP and Kumar S. 2014. *Fruit and Vegetable Preservation: Principles and Practices* (3rd Edition), CBS Publishing, ISBN 9788123924373.
- 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.

Websites

http://agriinfo.in/default.aspx?page=topic&superid=2&topicid=2065
http://www.fao.org/docrep/x0209e/x0209e02.htm
http://www.cstaricalcutta.gov.in/images/CTS%20Fruits_and_Vegetables%20NSQF.pdf

Course Code : PHM 506

Course Title : Laboratory Techniques in Postharvest Horticulture

Credit Hours : (1+2)

I. Why this course ?

To familiarize with the conventional analysis of raw and processed food products of all commodity technologies used for routine quality control in food industry, and their role on nutritional labeling. To develop an understanding and methodologies of instrumental techniques in food analysis used for objective methods of food quality parameters.

To familiarise with advances in instrumentation and Postharvest management

VI. Theory

Block 1: Laboratory Techniques in Postharvest Management

Unit I: Rheological techniques and instrumentation used in food industry. Analysis of food additives like food colour, antioxidants, emulsifier, etc.

Unit II: Analysis of pesticide residues, metallic contaminants, Analysis of food flavours.

Unit III: Quality analysis of processed fruits and vegetables, coffee, tea and spices. Identification and enumeration of microbial contaminants.

Unit IV: Principles of chromatography (GC, GCMS, HPLC, LCMS), spectrophotometry (Atomic absorption spectrophotometer, ICAP spectrophotometer), ICP-MS, ICPOES, NMR, ESR, amino acid analyser, flame photometry, electrophoresis.

Unit V: Colour measurement in foods, IRGA, Radio-isotopic techniques. Non destructive quality evaluation (NDQE)- E-nose, E-tongue, machine vision. electrophoresis.

VII. Practical

- Sample preparation for quality analysis. Energy calculation, sample calculations;
- Texture analysis, Rheology of different foods;
- Instrumental colour analysis;
- Sensory evaluation and microbiological examinations of fresh and processed products;
- Estimation of tannin/ phytic acid by spectrometric method;
- Moisture and fat analysis by NIR spectroscopy;
- Separation and identification of sugars in fruit juices;
- Separation and identification of carotenoids by column chromatography;

- Estimation of respiration in fruits and vegetables;
- Flavour profile in essential oils using GC;
- Identification and determination of organic acids by HPLC;
- Capsaicin content and Scoville Heat Units in chillies;
- Heavy metal analysis using atomic absorption spectrometry;
- Residue analysis.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations

IX. Learning outcome

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

- Techniques and instrumentation used in food industry
- Analysis of pesticide residues
- Quality analysis of processed fruits and vegetables
- Principles of chromatography and Spectrophotometry
- Non-destructive quality evaluation

X. Suggested Reading

- Lundanes E., Reubsaet L and Greibrokk T. 2013. *Chromatography: Basic Principles, Sample Preparations and Related Methods*, ISBN-13: 978-3527336203, Wiley VCH
- Mark F Vitha. 2016. *Chromatography: Principles and Instrumentation*. John Wiley & Sons, ISBN 9781119270881
- Suzanne NS. 2010. *Introduction to Food Analysis*, ISBN 978-1-4419-1478-1, Springer. Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, Tata McGraw-Hill ISBN 9780074518519.
- Semih Otles (Ed). 2016. *Methods of Analysis of Food Components and Additives* (*Chemical and Functional Properties of Food Components*) CRC Press, ISBN-13: 978-1138199149

Course Code : PHM 507
Course Title : Processing of Horticultural Produce
Credit Hours : (2+2)

I. Why this course ?

Postharvest system deals with ensuring the delivery of a crop from the time and place of harvest to the time and place of consumption, with minimum loss, maximum efficiency and returns to all concerned including grower, processors and consumer. The term 'system' represents a dynamic, complex aggregate of locally interconnected functions or operations within a particular sphere of activity. While, the term pipeline of operations refers to the functional succession of various operations but tends to ignore their complex interactions. Primary processing operations include washing/ cleaning, sorting, grading, dehulling, pounding, grinding, packaging, soaking, winnowing, drying, sieving, whitening and milling and secondary operations include mixing, cooking, drying, frying, moulding, cutting, extrusion product preparation.

II. Aim of the course

This course gives an overview of status of fruit and vegetable processing in the country, objectives and importance of preservation, important constraints and different unit operations processing industry which helps in expansion of industry and scope for further growth in this sector.

This course is organized as follows:

No	Blocks	Units
1	Importance and Thermal processes	I Scope and Importance II Thermal processes III Evaporation
2.	Processing equipment and enzyme kinetics	I Processing equipment and facilities II Enzyme kinetics

III. Theory

Block 1: Importance and Thermal processes

Unit I: Processing unit- layout and establishment, processing tools. Quality requirements of raw materials for processing, preparation of raw material, primary processing: grading, sorting, cleaning, washing, peeling, slicing and blanching; minimal processing.

Unit II: Preparation of various processed products from fruits and vegetables, flowers; role of sugar and pectin in processed products. Freezing of fruits and vegetables. Containers, equipment and technologies in canning.

Unit III: Juice extractions, clarification and preservation, recent advances in juice processing technology, application of membrane technology in processing of juices, preparation of fruit beverages and juice concentrate. Sensory evaluation.

Block 2: Processing equipment and enzyme kinetics

Unit I: Dehydration of fruits and vegetables using various drying technologies and equipment, solar drying and dehydration, packaging technique for processed products.

Unit II: Quality assurance and storage system for processed products. Nutritive value of raw and processed products, plant sanitation and waste disposal. Types of horticultural and vegetables wastes and their uses, utilization of by- products from fruits and vegetables processing industries.

IV. Practical

- Handling of harvesting equipments;
- Determination of physical and thermal properties of horticultural commodities;
- Thermal process calculations;
- Particle size analysis, Storage structure design;
- Numerical problems in freezing, drying, conveying and calculations pertaining to texture and Rheology;
- Handling of heating equipment, pulper, juice extractor, deaerator, juice filters;
- Processing industries waste treatment;
- Working of a canning unit;
- Visit to commercial processing units and storage units.

V. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations

VI. Learning outcome

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

- Unit operations of processing
- Planning for domestic as well as commercial storage and processing facilities
- Kinetics of growth and enzyme reaction

VII. Suggested Reading

- Karel M and Lund DB. 2003. *Physical Principles of Food Preservation* (2nd Edition), CRC Press, ISBN 9780824740634.
- Paul Singh R and Heldman DR. 2009. *Introduction to Food Engineering* (4th Edition), Academic Press, ISBN 9780123709004.

- Rao DG. 2010. *Fundamentals of Food Engineering*, PHI Learning Pvt. Ltd., ISBN 9788120338715.
- Ratti C. 2008. *Advances in Food Dehydration*, CRC Press, ISBN 9781420052527.
- Toledo RT. 2007. *Fundamentals of Food Process Engineering* (3rd Edition), Springer, ISBN 9780387290195.
- Smith PG. 2011. *Introduction to Food Process Engineering*, Springer, ISBN 9781441976611.

Course Code : PHM 508

Course Title : Quality Assurance, Safety and Sensory Evaluation ofFresh and Processed Horticultural Produce

Credit Hours : (2+1)

I. Why this course ?

The quality of fresh horticultural commodities is a combination of characteristics, attributes, and properties that give the commodity value for food (fruits and vegetables) and enjoyment (ornamentals). Producers are concerned that their commodities have good appearance and few visual defects, but for them a useful cultivar must score high on yield, disease resistance, ease of harvest, and shipping quality. To receivers and market distributors, appearance quality is most important; they are also keenly interested in firmness and long storage life. Although consumers buy on the basis of appearance and feel, their satisfaction and repeat purchases are dependent upon good edible quality. Assurance of safety of the products sold is extremely important to the consumers. Hence this customized course.

II. Aim of the course

To understand the quality and safety management system and the process of sensory analysis for horticultural products

This course is organized as follows:

No	Blocks	Units
1	Quality Assurance	I Concept of quality II Food laws and regulations I. Food safety II Quality management I.Introduction to sensory evaluation II Methods of sensory evaluation

III. Theory

Block 1: Quality Assurance

Unit I: Concept of quality: Quality attributes- physical, chemical, nutritional, microbial, and sensory; their measurement and evaluation. Concepts of quality management: Objectives, importance and functions of quality control; Quality management systems in India; Sampling procedures and plans.

Unit II: Food laws and regulations in India, Quality management standards, ISO, BIS, PFA, AGMARK and QMS standards, quality system components and their requirements.

Block 2: Safety

Unit I: Food safety and standards act (FSSA,2006); Strategies for compliance with international agri-food standards; Export specification and analysis and critical control points (HACCP), design and implementation of an HACCP system, steps in the risk management process. Traceability in food supply chains.

Unit II: Organic Certification, GAP, GMP, TQM. Indian and International quality systems and standard like, Codex Alimentarius, ISO, etc. Consumer perception of safety; Ethics in food safety.

Block 3: Sensory Evaluation

Unit I: Introduction to sensory analysis; general testing conditions, Requirements of sensory laboratory; organizing sensory evaluation programme. Selection of sensory panellists; Factors influencing sensory measurements; Sensory quality parameters -Size and shape, texture, aroma, taste, colour and gloss; Detection, threshold and dilution tests. Different tests for sensory evaluation–discrimination, descriptive, affective; Flavour profile and tests; Ranking tests.

Unit II: Methods of sensory evaluation of different food products. Designing of experiments. Handling and interpretation of Data. Role of sensory evaluation in product optimization. Relationship between objective and subjective methods. Sensory Analysis for consumer evaluation. Computer aided sensory evaluation of food and bewarage.

IV. Practical

Evaluation in product optimization. Relationship between objective and subjective methods. Sensory analysis for consumer evaluation. Computer-aided sensory evaluation of food and beverage.

- Analysis for TSS, pH, acidity, sugars, pectic substances, minerals, vitamin C, carotene, alcohol, benzoic acid and SO_2 contents, yeast and microbial examination in processed products;
- Demonstration of measurement of vacuum/ pressure, head space, filled weight, drained weight, cut-out analysis and chemical additives;
- Moisture content, rehydration ratio and enzymatic/ non-enzymatic browning in dehydrated products;

- Analysis of spices for quality parameters. Evaluation of processed products according to FSSAI specification;
- Selection and training of sensory panel;
- Identification of basic taste, odour, texture and colour;
- Detection and threshold tests; Ranking tests for taste, aroma, colour and texture; Sensory evaluation of various horticultural processed products using different scales, score cards and tests, Hedonic testing;
- Estimation of color and texture; optimising a product by sensory analysis;
- Studying relationship between objective and subjective methods.

V. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentation

VI. Learning outcome

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

- Concepts of quality management
- Food laws and regulation in India
- Export specification and guidelines by APEDA
- Consumer perception of safety and Ethics in food safety

VII. Suggested Reading

- Amerine MA, Pangborn RM and Rosslos EB. 1965. Principles of Sensory Evaluation of Food Academic Press.
- Curtis PA. 2005. *Guide to Food Laws and Regulations*, Wiley-Blackwell, ISBN 9780813819464.DGHS *Manual 8: Manual of Methods of Analysis of Foods-Food Additives*. Curtis PA. 2005. *Guide to Food Laws and Regulations*, Wiley-Blackwell, ISBN 9780813819464. Early R. 1995. *Guide to Quality Management Systems for the Food Industry*, Springer, ISBN 9781461358879.
- Kemp SE, Hollowood T and Hort J. 2009. *Sensory Evaluation: A Practical Handbook*, Wiley- Blackwell Publisher, ISBN 9781405162104.
- Krammer A and Twigg BA. 1973. Quality Control in Food Industry.Vol.I, II.AVI Publ.
- Lawless, Harry T, Heymann and Hildegarde. 2010. Sensory Evaluation of Food: Principles and Practices, Springer, ISBN 9781441964885.
- Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products,* Tata McGraw-Hill ISBN 9780074518519.
- Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit*

and Vegetable Products, Tata McGraw-Hill, ISBN 9780074518519.

- *The Food Safety and Standards Act, 2006 along with Rules & Regulations* 2011, Commercial Law Publishers (India) Pvt. Ltd.

Websites

https://en.wikipedia.org/wiki/Sensory_analysis
https://link.springer.com/chapter/10.1007/978-1-4757-5112-3_5
https://www.foodqualityandsafety.com/

Course Code : PHM 509
Course Title : Functional Foods from Horticultural Produce
Credit Hours : (2+0)

I. Why this course ?

Functional foods are foods that have a potentially positive effect on health beyond basic nutrition. This course examines the rapidly growing field of functional foods in the prevention and management of chronic and infectious diseases. It attempts to provide a unified and systematic account of functional foods by illustrating the connections among the different disciplines needed to understand foods and nutrients, mainly: food science, nutrition, pharmacology, toxicology and manufacturing technology. Advances within and among all these fields are critical for the successful development and application of functional foods

II. Aim of the course

To familiarise with functional foods from horticultural produce this course is organized as follows:

No	Blocks	Units
1	Functional food and importance	I Introduction, Sources and classification II Functional Ingredients
2.	Bioactive Compounds	I Introduction and classes of bioactive compounds II Mechanism of Neuroprotection
3.	Nutraceuticals	I Introduction, classification, role and health benefits

III. Theory

Block 1: Functional food and importance

Unit I: Functional foods- Introduction, definition, history; Importance, relevance and need of functional foods. Sources and classification of functional foods. Importance of horticultural produce as functional foods. Functional foods derived from fruits, vegetables, medicinal and aromatics.

Unit II: Functional ingredients and their properties. Therapeutic potential and effects of horticultural produce; Herbs, herbal teas, oils, etc. in the prevention and treatment of various diseases. Effect of preservation and processing on functional properties of horticulture produce.

Block 2: Bioactive Compounds

Unit I: Introduction, Classes of bioactive compounds present in fruits and vegetables. Polyphenols: Phenolic acid, Stilbenes, Flavonoids, Lignin, Coumarin, Tannin, etc. –their chemistry, source, bioavailability, interaction in food systems; changes during storage and processing. Alkaloids; Nitrogen Containing Compounds; Sulphur compounds; phytosterols; carotenoids; dietary fibres, etc.–their chemistry, source, bioavailability, interaction in food systems; changes during storage and processing.

Unit II: Mechanism of neuroprotection by bioactive compounds. Techniques of Extraction, purification and concentration of bioactive compounds from fruits and vegetables. Bioactive compound and health benefits Incorporation of bioactive compounds in foods.

Block 3: Neutraceuticals

Unit I: Nutraceuticals- Introduction, classification of nutraceuticals, dietary supplements, fortified foods, functional foods and phytonutraceuticals. Role of medicinal and aromatic plants in nutraceutical industry. Healthbenefits of phytoneutraceuticals.

IV. Teaching Methods/ Activities

1. Lectures
2. Assignment (Reading/ Writing)
3. Exposure visits
4. Student presentation

V. Learning outcome

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

- Importance of functional foods
- Functional ingredients and their properties
- Classes of bioactive compounds present in fruits and vegetables
- Mechanism of neuroprotection by bioactive compounds
- Importance of Nutraceuticals

VI. Suggested Reading

- Rosa LA, Alvarez-Parrilla E and Gonzalez-Aguilar GA. 2009. *Fruit and Vegetable Phytochemicals: Chemistry, Nutritional Value and Stability*, Wiley-Blackwell, ISBN 9780813803203.
- Senrawat R, Khan KA, Goyal MR and Paul PK. 2018. *Technological Interventions in the Processing of Fruits and Vegetables*, Apple Academic Press, ISBN 9781771885867.
- Vattem DA. 2016. *Functional Foods, Nutraceuticals and Natural Products: Concepts and Applications*. DEStech Publications, Inc, ISBN 978 1 60595 101 0.

- Watson RR and Preedy V. 2009. *Bioactive Foods in Promoting Health: Fruits and Vegetables* (1st Edition), Academic Press, ISBN 9780123746283

Course Code : PHM 510
Course Title : Marketing and Entrepreneurship in Post Harvest Horticulture
Credit Hours : (1+1)

I. Why this course ?

To develop marketing strategies and equip individuals to start their own food service.To develop Techniques for the development of entrepreneurial skills, positiveself image and locus of control.

II. Aim of the course

To understand the market channel and appraise entrepreneurship opportunity in postharvest operations.

This course is organized as follows:

No	Blocks	Units
1	Marketing and entrepreneurship	I .Entrepreneurship in processing industry II Business Plan III MSME Enterprise IV Marketing V Institutional supports

Theory

Unit I: Entrepreneurship – Concept, need for entrepreneurship – Types of entrepreneurs -entrepreneurial opportunities in horticultural processing sector-Government schemes and incentives for promotion of entrepreneurship in processing sector.

Unit II: Writing Business Plan- Business Plan Format for Small and micro Enterprises-Generation, incubation and commercialization of business ideas – Environment scanning and opportunity identification.

Unit III: Steps in establishment of MSME Enterprise – Planning of an enterprise – Formulation and project report-Meaning – Importance Components and preparation.-Government Formalities and Procedures.

Unit IV: Marketing potential of processed products at domestic and international level-Marketing management-Marketing functions, market information and market research-Problems in marketing of processed products- Demand and supply analysis of important processed products- Marketing channels – Marketing strategy (product strategy and pricing strategy)- Supply chain management – Meaning, importance, advantages, supply chain management of important processed products.

Unit V: Institutional support to Entrepreneurship Role of Directorate of

Industries, District Industries, Centres (DICs), Industrial Development Corporation (IDC), State Financial corporation (SFCs), Commercial banks Small Scale Industries Development Corporations (SSIDCs), Khadi and village Industries Commission (KVIC), National Small Industries Corporation (NSIC), Small Industries Development Bank of India (SIDBI).

III. Practical

- Consumer Behaviour towards Processed Foods;
- An Empirical Test-Carrying out the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of successful Enterprises;
- Constraints in setting up of horti based industries;
- Field visits to study any one of the Local Financial Institutions to study the MSME Policies;
- Preparation of business plan and proposal writing-Project evaluation techniques;
- Discounted and undiscounted techniques;
- Case studies of successful entrepreneurs.

IV. Teaching Methods/ Activities

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

V. Learning outcome

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

- Concept of entrepreneurship
- Writing Business Plan
- Steps in establishment of MSME Enterprise
- Marketing management
- Institutional support to Entrepreneurship

VI. Suggested Reading

- Adhikary MM. 2014. *Enterprise and Entrepreneurship for Agri-Business Management and Planning*. Daya Publishing House. New Delhi
- Bhaskaran S. 2014. *Entrepreneurship Development and Management*. Aman Publishing House, Meerut.
- Choudhury M and Barua N. 2014. *Marketing of Processed Fruit and Vegetable*. Daya Publishing House. New Delhi.
- Gaur SC. 2012. *Handbook of Agro Food Processing and Marketing*. Agrobios. Jodhpur
- Kadam MM and Bishe RN. 2018. *Textbook on Agricultural Entrepreneurship*. Narendra publishing house. New Delhi.
- Sudheer KP and Indira V. 2018. *Entrepreneurship and Skill Development in Horticultural Processing*. New India Publishing Agency. New Delhi.
- Sudheer KP and Indira V. 2018. *Entrepreneurship Development in Food Processing*. New India Publishing Agency. New Delhi.

Course Code : PHM 511
Course Title : Value Addition and Processing of Planation Crops and Spices
Credit Hours : (2+1)

I. Why this course ?

Plantation crops & spices occupy a predominant position in the agricultural economy of the state. Apart from foreign exchange earnings, organic spices, value added spices like oils and oleoresins are assuming significance. Post harvest operations like processing, extraction and development of value added products play a major role in maintaining quality of plantation crops and spices to the specifications of international trade. Clear and comprehensive understanding of postharvest deteriorative factors is necessary to overcome the challenges in serious postharvest losses. Studying these aspects is important in the establishment of a profitable production enterprise based around plantation crops, spices and essential oils. Hence this customized course

II. Aim of the course

To facilitate deeper understanding on the principles and practices of processing and value addition of plantation crops and spices.

This course is organized as follows:

No	Blocks	Units
1.	Value addition and processing of plantation crops	I. Importance , Commercial uses of spices and plantation crops. Trading II. Processing and value addition
2.	Processing and value addition of spices	I. Major spices II. Tree spices III. Seed spices and minor spices IV. Innovations in value addition

III. Theory

Block 1: Value addition and processing of plantation crops

Unit I: Importance of plantation crops and spices in the economy of state of nation. Commercial uses of spices and plantation crops. Trading of plantation crops, spices and products in domestic and export markets.

Unit II: Processing and value addition of plantation crops, viz., Coffee, Tea, Cocoa, Cashew nut, Coconut, Oil Palm, Arecanut, Rubber, Palmyrah palm .

Block 2: Processing and value addition of spices

Unit I. Processing and value addition of major spices, viz., Black Pepper, Cardamom, Ginger, Turmeric, Chilli and Paprika.

Unit II. Processing and value addition of tree spices:- Clove, Nutmeg, Cinnamon, Allspice, Camboge.

Unit III. Processing and value addition of Seed spices and minor spices coriander, cumin, fennel, fenugreek, curry leaf and vanilla.

Unit IV. Innovations in value addition of plantation crops: virgin coconut oil, desiccated coconut, spray dried coconut powder, preservation of coconut inflorescence sap etc. Utilization of arecanut spathe for diversified uses. Modern method of chocolate manufacture. Decaffeinated coffee, Green tea, Oolong tea, Organic tea etc. Hi-tech processing for extraction of essential oils and oleoresins from spices. Encapsulated spice flavours, extruded spices, essences, drops, nutraceuticals, pigment and aromatics.

IV. Practical

- Identification of different products of plantation crops and spices.
- Familiarizing different grades of plantation crops, spices and their products.
- Preparation of refined coconut oil, preserving tender coconut water and vinegar.
- Production of clarified juice, syrup and wine from cashew apple.
- Fermentation of cocoa beans and production of chocolate.
- Extraction of spice oleoresins and essential oils.
- Preparation of dried and dehydrated products from spices.
- Preparation of white pepper.
- Preparation of spice powders and curry powders.
- Visit to processing units of plantation crops and spices.
- Quality control of spices (adulteration in spice products) and plantation products.

V. Teaching Methods/ Activities

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

VI. Learning outcome

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

- Familiarizing with different value added products from plantation crops
- Familiarizing with different value added products from spices
- Method of processing of spices and plantation crops
- High tech processing methods

VII. Suggested Reading

- Bavappa, K.V.A., Nair, M.K., Premkumar, T. 1982. *The Arecanut Palm Monograph series*. CPCRI, Kasaragod.
- Chadha KL et al. (Eds.). 1993-95. *Advances in Horticulture*. Vol. IX *Plantation Crops and Spices*. Malhotra Publishing House, NewDelhi.

- Coreley,R.H.V., Harden,J.J., Wood,H.J. 1976. *Oil Palm Research and Development*. Crop Science-I. Longman, New York.
- Mandal, RC. 1997. *Cashew: Production and Processing Technolog*y. Agro.Bot.
- Masada ,Y.1986. *Analysis of Essential Oil by Gas Chromatograph and Mass Spectrometr*y. John Wiley & Sons.
- Peter, K.V. 2001. *Hand Book of Herbs and Spices*. Vols. I-III. Woodhead Publ. Co., UK & CRC, USA.
- Pruthi,J.S. 1993. *Major Spices of India. Crop Management and Post Harvest Technology*. ICAR, New Delhi.
- Thampan, P.K. 1984. *Handbook on Coconut Palm*. Oxford and IBH Pub. Co. New Delhi.

Course Code : PHM 512
Course Title : Value Addition of medicinal and aromatic plants
Credit Hours : (2+0)

I. Why this course ?

Economic importance of medicinal and aromatic plants is much more to countries such as India than to rest of the world. They occupy a predominant position in the agricultural economy of the state. Post harvest operations like processing, extraction and development of value added products play a major role in maintaining product quality to the specifications of international trade. Clear and comprehensive understanding of postharvest deteriorative factors is necessary to overcome the challenges in serious postharvest losses. Hence this customized course

II. Aim of the course

To educate the principles and practices of processing and value addition of medicinal and aromatic crops.

This course is organized as follows:

No	Blocks	Units
1.	Introduction	I. Importance , Scope & prospects
2.	Processing and value addition	I. Medicinal plants II. Aromatic plants III. Seed spices and minor spices IV. Innovations in value addition
3.	Active principles	I. Extraction and analysis methods II. Utilization of active principles III. Quality control & standard specifications

III. Theory

Block 1. Introduction

Unit I : Importance and scope of medicinal and aromatic crops. Scope in modern medicine, ayurveda and indigenous system of medicine. Prospects of processing and value addition of medicinal and aromatic crops for utilization in the pharmaceutical, nutraceutical, flavour and perfumery industries.

Block2. Processing and value addition

Unit I.: Processing and value addition of medicinal plants, viz., Catharanthus, Dioscorea, Solanum, Datura, Rauvolfia, Acorus, Digitalis, Ephedra, Opium Poppy, Cannabis, Neem, Kaempferia, Plumbago, Alpinia, Adhatoda, Isabgol, Liquorice, Aloe, Safed musli, Sapan wood, Withania, Gloriosa, Stevia, Coleus.

Unit II.: Processing and value addition of aromatic plants, viz., Lemon grass, Palmarosa, Vetiver, mint, Rose, tube rose, Rosemary, Eucalyptus, Sandalwood, Geranium, Jasmine, Patchouli, Lavender, Tulsi, Davana, Citronella etc.

Block3. Active principles

Unit I : Extraction and analysis of active principles using TLC,GC, HPLC,Hydro-distillation, solvent extraction, enfleurage.

Unit II : Utilization of active principles of medicinal plants in the pharma sector. Study of aroma compounds of aromatic plants and their utilization in the perfumery industries. Quality control & standard specifications in essential oils. Nano-processing technology in medicinal and aromatic plants.

IV. Teaching Methods/ Activities

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

V. Learning outcome

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

- Familiarizing with different value added products from medicinal plants
- Familiarizing with different value added products from aromatic plants
- Method of processing
- Active pinciples

VI. Suggested Reading

- Chadha,K.L. and Gupta. R. 1995. *Advance in Horticulture* Vol. 11 Medicinal & Aromatic plants.Malhotra Pub. House, New Delhi.
- Handa,S.S. and M.K. Kabul. 1996. *Supplement to Cultivation and Utilization of Medicinal Plants* RRL (CSIR) Jammu- Tawi.

- Kirthikar,K.R. and Basu,B.D.1993. *Indian Medicinal Plants*, Vol. 1-4. Lalit Mohan Basu, Allahabad.
- Kurian, A.and Sankar, M.A.2007. *Medicinal Plants*. New India Publishing Agency, New Delhi.
- Sudeer, K.P. and Indira,V.2008. *Post –Harvest Technology of Horticultural crops, Horticulture Science Series*. New India Publ. Agency.

Course Title with Credit Load for Ph.D (Hort.) in Postharvest Management

Course Code	Course Title Credit	Hours
PHM 601**	Ripening and Senescence of Fruits and Vegetables	1+1
PHM 602**	Recent Trends in Food Preservation	1+1
PHM 603	Management and Utilization of Horticultural Processing Waste	3+0
PHM604**	Supply Chain Management of Perishables	2+0
PHM 605	Export Oriented Horticulture	1+0
PHM 606	Food Additives	1+1
PHM 607	Advances in Processing of Plantation, Spices, Medicinal and Aromatic Plants	3+0
PHM 608	Value Addition in Ornamental Crops	1+1
	Minor courses	06
	Supporting courses	05
PHM 691	Seminar I	0+1
PHM 692	Seminar II	0+1
PHM 699	Research	0+75
	TOTAL	**100**

*Compulsory among major courses

Course Title : Ripening and Senescence of Fruits and Vegetables
Course Code : PHM 601
Credit Hours : (1+1)

I. Why this course ?

Fleshy fruit experiences profound physiological, biochemical, and structural modifications during ripening to facilitate seed dispersal and to become attractive and nutritious for human consumption. The metabolic networks regulating fruit ripening are very complex, and ethylene appears to be a key factor acting in concert with other environmental signals and endogenous factors. The classical distinction between climacteric and nonclimacteric ripening is now questionable, as different patterns of synthesis and sensitivity to ethylene may operate in the ripening of different fruits. In recent years, much progress has been done in the characterization of the main biochemical pathways implicated in the different ripening-associated processes and in the identification of key genes controlling these events. This course highlights current understanding and advances in the regulation of fruit ripening and key metabolic pathways associated with the different ripening-related processes, with emphasis on their impact on fruit quality.

II. Aim of the course

To impart knowledge about physiological and molecular changes during senescence and ripening.

III. Theory

Unit I: Environmental factors influencing senescence, ripening and post harvest life of fruits, flowers and vegetables.

Unit II: Molecular mechanism of senescence and ageing.Physiological, biochemical and molecular aspects of senescence and fruit ripening. Senescence associated genes and gene products.

Unit III: Functional and ultra structural changes in chloroplast membranes, mitochondria and cell wall during senescence and ripening.

Unit IV: Ethylene biosynthesis, perception and molecular mechanism of action; regulatory role of ethylene in senescence and ripening, biotechnological approaches to manipulate ethylene biosynthesis and action.

Unit V: Alternate post harvest methodology and quality attributes. Scope for genetic modification of post harvest life on flowers and fruits. Uses of GM crops and ecological risk assessment.

IV. Practical

- Physiological and biochemical changes during senescence and ripening;
- Estimation of ethylene during senescence and ripening;
- Determination of Reactive Oxygen Species and scavenging enzymes;

- Measurement of dark and alternate respiration rates during senescence and ripening;
- Estimation of ripening related enzyme activity, cellulases, pectin methyl esterases, polygalacturonase, etc.

V. Teaching Methods/ Activities

- Lectures
- Assignments (Readomg/ writing)
- Student presentation

VI. Learning outcome

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

- Physiological, biochemical and structural changes during scenecesnce and ripening.

VII. Suggested Reading

- Bartz JA and Brecht JK. 2003. *Post harvest physiology and pathology of vegetables*. Marcel Dekker Inc.
- Davis PJ. 2004. *Plant Hormone: Biosynthesis, Signal transduction and action*. Kluwer Academic Publishers.
- Dris R and Jain SM. 2004. *Production practices and quality assessment of food crops*, Vol. 4: Post harvest treatment and Technology. Kluwer Academic Publisher.
- Khan NA. 2006. *Ethylene action in plants*. Springer Verlag.
- Knee M. 2002. *Fruit Quality and its Biological Basis*. Sheffield Academic Press, CRC Press. Nooden LD. 2004. *Plant cell death processes*. Elsevier Science, USA.
- Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Post harvest biology and technology of fruits, vegetables and flowers*. Blackwel Publishing, Iowa, USA.
- Seymour G, Taylor J and Tucker G. 1993. *Biochemistry of fruit ripening*. Edited Chapman andHall, London.
- Valpuesta V. 2002. *Fruit and vegetable biotechnology*.Woodhead Publishing Limited, Cambridge, England.

Course Title : Recent Trends in Food Preservation

Course Code : PHM-602

Credit Hours : (1+1)

I. Why this course ?

Commendable production with short storage life and strategic selling limits the produce to huge loss after harvest. To prevent the postharvest loss preservation of produce with appropriate technique enhances the finished product shelf life nearly 10 to 30 times. Food processing combines raw food ingredients to produce marketable food products that can be easily prepared and served by the consumer. Emerging technologies which have already found in the food industry or related sector are High pressure processing, pulsed electric fields, ultrasound, and cold plasma. The basic principles of these technologies as well as the state of the art concerning their impact on biological cells, enzymes, and food constituents.

II. Aim of the course

The present subject imparts knowledge on recent advancement in food preservation technologies. The basic principles of preservation technologies as well as the state of the art concerning their impact on biological cells, enzymes and food constituents.

Current and potential applications will be discussed, focusing on process-structure- function relationships, as well as recent advances in the food process development that make foods.

The course is organized as follows:

No	Blocks	Units
1	Hurdle technology and recent advances	I Hurdle technology II Thermal and Non-thermal technology III Recent food preservation techniques
2	Enzyme applications and quality parameters	I Enzyme and their applications II Quality specifications and standards

III. Theory

Block 1: Hurdle technology and recent advances

Unit I: Hurdle technology, Principles of Hurdle Technology, Minimally Processed foods, Intermediate moisture foods, role of water activity in food preservation, Chemicals and biochemicals used in Food Preservation- Natural food preservatives, bacteriocins.

Unit II: Thermal and Non-thermal technology, Advanced Thermal and Nonthermal Technology- Pulsed electric field, microbial inactivation, application, present status and future scope. Fundamentals and Applications of High Pressure Processing to Foods, Advances in Use of High Pressure to Processing and Preservation of Plant Foods, Commercial High-Pressure Equipment. Food Irradiation – an Emerging Technology.

Unit III: Recent food preservation techniques, Ultraviolet Light and Food Preservation; Microbial Inactivation by Ultrasound; Use of oscillating Magnetic Fields. Nonthermal Technologies in Combination with Other Preservation Factors. Preservation by ohmic heating-Advances in Ohmic Heating and Moderate Electric Field (MEF) Processing; Radio- Frequency Heating in

Food Processing; Current State of Microwave Applications to Food Processing .Supercritical Fluid Alternative to Isolating bioactive compounds.

Block 2: Enzyme applications and quality parameters

Unit I: Enzyme and their applications. Enzyme and their application in food processing, Principles of food biotechnology, fermentation and enzyme mediated food processing, production of high value products such as Single Cell Protein, nutritional additives, pigments and flavours.

Unit II: Quality specifications and standards. Quality parameters and specifications, Food laws and standards, HACCP, FSSAI amendments, ISO, FDA.

IV. Practical

- Determination of thermal resistance of food spoilage microorganisms;
- Determination of thermal death curve;
- Thermal process calculations;
- Demonstration of hurdle approaches in fruits and vegetables preservation.
- Detection of microbes in each hurdle. Study of shelf life of fresh cut produce ineach hurdle;
- Study of fresh cut produce packing, storage temperature and microbial interaction;
- Study of thermal and non thermal application in food preservation;
- Study of moisture content in food their water activity;
- Demonstration of microwave technology in fresh produce preservation and drying;
- Determination of dry matter content in food using microwave technology;
- Study the use of enzymes in different fruit juice extraction, quantification, time –Pectinase/cellulose and others;
- Incubation techniques of enzymes using fermenter for juice extractions;
- Group discussions on current market potential of hurdle technology – Prose andcons;
- Visit to advanced food processing unit;
- Visit to SCFE unit.

V. Teaching Methods/ Activities

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

VI. Learning outcome

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

- Understand the latest methods and techniques in preservation of food particularly of horticultural produce

VII. Suggested Reading

- Barbosa CGV, Pothakamury UR, Palou E and Swanson BG. 1998. *Nonthermal Preservation of Foods*, Marcel Dekker Inc., ISBN 9780824799793.
- Karel M and Lund DB. 2003. *Physical Principles of Food Preservation* (2nd Edition), CRC Press, ISBN 9780824740634.
- Sun Da-Wen (Ed.) 2014. *Emerging Technologies for Food Processing* (2nd Edition), Elsevier, ISBN 9780124114791.
- Tewari G and Juneja V. 2007. *Advances in thermal and nonthermal food.* Blackwell Publishing, ISBN 9780813829685.

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- http://www.ijpab.com/form/2017%20Volume%205,%20issue%206/IJPAB-2017-5-6-363-371.pdf
- https://www.omicsonline.org/conferences-list/food-processing-technologies-and-advances-in-food-preservation
- https://www.elsevier.com/books/advances-in-cold-plasma-applications-for-food-safety-and- preservation/bermudez-aguirre/978-0-12-814921-8

Course Code: PHM-603

Course Title: Management and Utilization of Horticultural Processing Waste

Credit Hours: (3+0)

I. Why this course ?

Processing of fruit and vegetables generates varying level and kinds of wastage that can be managed differently. With the rapid progress in establishment of processing industries in our country on account of liberal government policies, the importance of waste management has become an essential and integral part of plant design as the inappropriate disposal of wastage has already caused great loss to environment and public health. Food processing is a capital intensive, high energy and water consuming, and moderate to highly polluting industry. However, one can minimize adverse effects on environment and public health and may also augment profit of processing unit by judicious disposal and utilization of waste materials. They can be used in composting, cattle feeding and biogas generation and certain types may also be utilized in production of value added products.

II. Aim of the course

Understanding the utilization and efficient management of waste from horticultural processing industry.

The course is organized as follows:

No	Blocks	Units
1	Waste treatment and disposal methods	I Introduction II Waste treatment processes III Waste disposal methods
2	Valorisation of wastes	I Recovery of useful products II Treatment of solid and liquid waste

III. Theory

Block 1: Waste treatment and disposal methods

Unit I: Introduction: Waste and its consequences in pollution and global warming. Need for waste management. Waste and its classifications and characterization-sampling methods, analysis and standards for waste discharge. Importance of point and nonpoint sources of wastes, Solid and liquid wastes.

Unit II: Waste treatment processes: BOD, COD, DO, TS VS, ash, and different unit operations in waste treatment processes.

Unit III: Waste disposal methods: Nature of waste from processing industry and their present disposal methods. Waste segregation, Primary secondary and tertiary waste treatment processes, Conventional and non-conventional waste treatment processes, aerobic and anaerobicwaste treatment processes.

Block 2: Valorisation of wastes

Unit I: Recovery of useful products: Valorization of wastes: Recovery of useful products and by-products from waste, viz., organic acids, bioethanol, biobutanol, colour, essence, pectin, oils, etc. animal feed and single cell protein.

Unit II: Treatment of solid and liquid waste: Technology of treatment of solid and liquid wastes from fruit and vegetable industries. Immobilized bioreactor in waste treatment.Anaerobic bioreactor and energy production.Circular economics and waste management.

IV. Teaching Methods

- Lectures
- Assignments (Reading/ Writing)
- Student presentations

V. Learning outcome

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

a. Can identify the problems related waste treatments and disposal methods

b. Problem related valuation of waste and recycling of waste

VI. Suggested Reading

- Arvanitoyannis IS. 2008. *Waste Management for the Food Industries*, Academic Press, ISBN 9780123736543.
- Joshi VK and Sharma SK. 2011. *Food Processing Waste Management: Treatment and Utilization Technology*, New India Publishing Agency, ISBN 9789380235592.
- Waldron K. Ed. 2007. *Handbook of waste management and co-product recovery in food processing*, CRC Press, ISBN 9780849391323.
- **Websites**
- https://www.cabdirect.org/cabdirect/abstract/20153005486
  http://www.3rmanagement.in/service/horticulture-waste-management/

Course Code : PHM 604

Course Title : Supply Chain Management of Perishables

Credit Hours : (2+0)

I. Why this course ?

Supply chain management is the management of the flow of goods and services and includes all processes that transform raw materials into final products. It involves the active streamlining of a business's supply-side activities to maximize customer value and gain a competitive advantage in the marketplace. SCM represents an effort by suppliers to develop and implement supply chains that are as efficient and economical as possible. Supply chains cover everything from production to product development to the information systems needed to direct these undertakings. Because of this, effective supply chain management also requires change management, collaboration and risk management to create alignment and communication between all the entities.

II. Aim of the course

To understand the intricacies of perishable supply chain and its management. The course is organized as follows:

No	Blocks	Units
1	Supply chain management of	I Introduction perishables II Intrinsic Issues III Support system in supply chain- – Infrastructure IV. Support system in supply chain- Finance V. Support system in supply chain- Government

III. Theory

Block 1: Supply chain management of perishables

Unit I: Introduction. Role of supply chain and logistics, Challenges faced in supply chain, Input suppliers, Farm output: Market intermediaries, Processors, Retailers.

Unit II: Intrinsic Issues: Perishability, Quality, Grading, Risk: Sources of risk, Classification of Agricultural risk- Production risk, Market and Price risk. Management of risk.

Unit III: Support system in supply chain- Infrastructure: definition, role. Transport network, Cold storage, organised market, etc. Information technology-Enterprise resource planning, E-Choupal, Mobile Technology, web portal on agri-market information.

Unit IV: Support system in supply chain- Financial Systems: Introduction, Role and Relevance, Problems in Synchronization, Role of Technology; Credit Structure in India -Reserve Bank of India (RBI), NABARD; Commodity Markets, Corporates in Agribusiness.

Unit V: Support system in supply chain- Role of Government: Introduction; Agencies- As a Direct Player. Measures for improving supply chain and its effectiveness, involvement of organized retailers.

- Present scenario of supply chain management;
- Case Study: Supply chain management of fruits and vegetables in Safal daily fresh/ APMC/ Reliance Fresh/ Amul/ D-Mart/ Spencer Retail/ Vipani/ Farmers Bazars/ Farm Fresh/ Apni Mandi, etc. based on regional importance.

IV. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/ Writing)
- Student presentationz

V. Learning outcome

After successful completion of this course, the students are expected to identify the problems related to supply chain management of perishables.

VI. Suggested Reading

- Chandrasekaran N and Raghuram G. 2014. *Agribusiness Supply Chain Management*, CRC Press, ISBN 9781466516755.
- Chopra S and Meindl P. 2007. *Supply chain management: strategy, planning, and operation* (3rd Edition), Pearson Education, Inc.,ISBN 0132086085.

Websites

http://www.scmr.com/ https://blog.kinaxis.com/
http://www.supplychainnetwork.com/ http://supplychaininsights.com/
http://www.supplychain247.com/

Course Code : PHM-605
Course Title : Export Oriented Horticulture
Credit Hours : (1+0)

I. Why this course ?

This course relates the national economy which is dependent on the contribution of the export-oriented income. Export oriented policies and laws must be followed by the growers to meet the requirement of the importing countries.

II. Aim of the course

To acquaint the students with the export oriented requirements of horticultural crops.

The course is organized as follows:

No	Blocks	Units
1	Product specifications and sanitary measures	I Introduction II Produce specifications and standards III Export oriented sanitary measures
2	Export related policies	I Export implications II Treatment of solid and liquid waste

III. Theory

Block 1: Product specifications and sanitary measures

Unit I: Introduction: India's position and potentiality in world trade; export promotion zones in India. Export and import policy, problem in export of fresh horticultural produce, export infrastructure (sea port, airport, bulk storage facilities, irradiation, Vapour Heat Treatment, quarantine, transportation, etc.,).quarantine need, major export destination and competing nations for selected crops.

Unit II: Produce specifications and standards: Scope, produce specifications, quality and safety standards for export of fruits, viz., mango, grape, litchi, pomegranate, walnut, cashewnut, etc., vegetables, viz., onion, chilli, okra, bitter gourd, gherkin, etc., flowers, viz., rose, carnation, chrysanthemum, gerbera, specialty flowers, etc., cut green and foliage plants.

Unit III: Export oriented sanitary measures: Processed and value-added products, Postharvest management for export including packaging and cool chain; HACCP, Codex alimentarius, ISO certification; APEDA and its role in export, WTO and its implications, sanitary and phyto-sanitary measures. Codex norms and GAP and SOP for export of major horticultural crops from India.

Block 2: Export related policies

Unit I: Export implications: Export of seed and planting material; implications MRL for export of horticultural produce.

Unit II: Export oriented regulatory issues: Agriculture Export Policy, Export procedure; EXIM Policy, APMC act, Auction Centres, Regulatory issues of Ministry of Commerce, GoI.

Teaching methods

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

IV. Learning outcome

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

- entry barriers, covering issues such as economies of scale, high capital investments, difficult access to distribution channels and markets, etc.
- bargaining power of buyers, which relates to issues such as the level of concentration of buying power, buyers' access to information, switching opportunities and costs, etc.

V. Suggested Reading

- Bartz JA. and Brecht JK. 2002. *Postharvest Physiology and Pathology of Vegetables* (IInd Edition) Marcel Dekkar, Inc, New York.
- Bhattacharjee, SK. 2006. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Bose TK and Yadav LP. 1989. *Commercial Flowers*. NayaProkash, Kolkata. Bose TK, Maiti

  RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. NayaProkash.
- Chadha KL. 1995. *Advances in Horticulture*. Vol. XII. Malhotra Publ. House.
- Islam CN. 1990. *Horticultural Export of Developing Countries: Past preferences, future prospects and policies*. International Institute of Food Policy Research, USA.
- Reddy S, Janakiram T. Balaji T, Kulkarni S and Misra RL. 2007. *Hightech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi.
- Sheela VL. 2007. *Flowers in Trade*. New India Publ. Agency.

Course Code : PHM 606

Course Title : Food Additives

Credit Hours : (1+1)

I. Why this course ?

Food additives have been used for centuries to improve and preserve the taste, texture, nutrition and appearance of food. Food additives and preservatives are used in today's food supply to prevent foodborne illness, enable the transportation of food to areas that otherwise wouldn't be possible, and for the efficient manufacture of products to consistently meet the established quality standards. Although there may be certain ill effects of additives and preservatives in food, they increase its shelf life and help retain the flavour, color, and texture. They also help maintain or increase the nutritive value of food. Hence this customized course.

II. Aim of the course

To understand the chemistry of food additives and their functions in food processing This course is organized as follows:

No	Blocks	Units
1	Quality control of horticultural products preservation	I Importance of food additives II Methods of III Different additives types IV Flavour technology V Use of functional ingredients and safety and toxicological evaluation

Theory

Block 1: Food Additives

Unit I: Importance of food additives in processing and preservation of horticultural produce by food additives. Food additives-definitions, classification, international numbering systems and functions.

Unit II: Principles and methods of preservation by use of sugar, salt, spices, essential oils, vinegar, mode of action of chemical preservatives.

Unit III: Antioxidants, colours and flavours (synthetic and natural), emulsifiers, sequester ants, humectants, hydrocolloids, sweeteners, acidulants, buffering salts, anticaking agents, clarifying agents, etc. – uses in horticulture foods and functions in formulations.

Unit IV: Flavour technology: types of flavours, flavour generated during processing – reaction flavours, flavour composites, stability of flavours during food processing, flavour emulsion, essential oils and oleoresins, etc.

Unit V: Uses of enzymes in extraction of juices. Pectic substances and their role as jellifying agents.Protein, starches and lipids as functional ingredients, functional properties and applications in horticultural food. Safety and toxicological evaluation of food additives: GRAS-tolerance levels and toxic levels in foods, LD_{50} value.

III. Practical

- Extraction of fruit and vegetable juices using enzymes clarification;
- Role of additives and preservatives in RTS, cordial, squash, concentrate, syrup, jam, jelly, marmalade, ketchup, sauce, preserves, chutneys, pickles, candies, crystallized products;
- Estimation of benzoic acid, sulphur-di-oxide;
- Estimation of pectins.

IV. Teaching Methods/ Activities

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

V. Learning outcome

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

- Importance of food additives in processing and preservation of horticultural produce
- About Flavour technology
- Safety and toxicological evaluation of food additives

VI. Suggested Reading

- Branen AL, Davidson PM, Salminen S and Thorngate III JH. 2001. *Food Additives* (2nd Edition), Marcel Dekker Inc., ISBN 0824793439.
- DGHS Manual 8: *Manual of Methods of Analysis of Foods-Food Additives*. Gerorge. AB. 1996. *Encyclopedia of Food and Color Additives*. Vol. III. CRCPress.
- Madhavi DL, Deshpande SS and Salunkhe DK. 1996. *Food Antioxidants: Technological, Toxicological and Health Perspective*. Marcel Dekker.
- Michael and Ash I. 2008. *Handbook of Food Additives* (3rd Edition), Synapse Information Resources, Inc., ISBN 9781934764008.
- Nagodawithana T and Reed G. 1993. *Enzymes in food processing*. Academic Press. (Ötleº S.) Ed. 2005. *Met of Analysis of Food Components and Additives*, CRC Press, ISBN 9780849316470.
- Taylor AJ. and Linforth RST. 2010. *Food Flavour Technology* (2nd

Edition), Wiley- Blackwell, ISBN 9781405185431.

- Wood R, Foster L, Damant A and Key P. 2004. *Analytical Methods for Good Sdditives*, CRC Press, ISBN 084932534X.

Websites

- Additives and colors FDA- https://www.fda.gov/food/ingredientspackaginglabeling/ food additivesingredients/ucm094211.html
- https://www.faia.org.uk/
- https://www.eufic.org/en/whats-in-food/category/additives

Course Code : PHM-607

Course Title : Advances in Processing of Plantation, Spices, Medicinal and Aromatic Plants

Credit Hours : (3+0)

I. Why this course ?

This course deals with post-harvest operations, processing and value addition details of plantation, spices, medicinal and aromatic plants. This course would be very useful for everyone who so ever is interested to know about harvesting and handling of spices, plantation, medicinal and aromatic plants.

II. Aim of the course

To familiarize with advances in processing of plantation, spices, medicinal and aromatic plants

The course is organized as follows:

No	Blocks	Units
1	Handling and utilization of plantation, spice, aromatic plants	I Introduction medicinal and II By product utilization III Value addition of medicinal and aromatic plants
2	Essential oil utilization and their storage	IV. Recovery of useful products V. Treatment of solid and liquid waste

III. Theory

Block 1: Handling and utilization of plantation, spice, medicinal and aromatic plants

Unit I: Introduction: Commercial uses of spices and plantation crops. Introduction to processing and products in plantation and spice crops. Significance of on farm processing and quality of finished products. Processing of major spices, extraction of oleoresin and essential oils. Processing of produce from plantation and spice crops.

Unit II: By product utilization: By product utilization in plantation crops for coir production, mushroom culture, cocopeat, bee keeping, toddy tapping, Oil cake production and utilization, vermi-composting, Fuel wood and timber wood from perennial spices and plantation crops (crops, viz., coconut, areca nut, cashew nut, oil palm, palmyrah, date palm, cocoa, tea, coffee, rubber, etc. cardamom, black pepper, ginger, turmeric, chilli and paprika, vanilla, cinnamon, clove, nutmeg, allspice, coriander, fenugreek, curry leaf, etc.).

Unit III: Value addition of medicinal and aromatic plants: Value addition on aromatic oils and medicinal herbs. Principles and practices of different types of extraction – distillation, solvent extraction, enfleurage, soxhlet, supercritical fluid extraction, phytonics, counter current extraction. Commercial uses of essential oils, aroma therapy.Commercial utilization of spent material.

Block 2: Essential oil utilization and their storage

Unit I: Quality determination of essential oils: Qualitative determination of essential oils. Quality analysis and characterization through chromatographs.

Unit V: Storage of essential oils: Storage of essential oils. Utilization of spent material of medicinal and aromatic crops in manufacture of agarabatti, organic manures and other useful products. Detoxification of waste materials. Role of spent material in bio-control of diseases and pest in organic farming. Role of micro-organisms in conversion of waste in to useful products.

IV. Teaching Methods/ Activities

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

V. Learning outcome

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

- Learn utilization and processing of spice, plantation, medicinal and aromatic plants
- Apply appropriate processing technique to the crop related processing technique

VI. Suggested Reading

- Afoakwa EO. 2016. *Cocoa Production and Processing Technology*, CRC Press, ISBN 9781138033825.
- Chakraverty A, Majumdar AS, Raghavan GSV and Ramaswamy HS. 2003. *Handbook of Postharvest Technology: Cereals, Fruits, Vegetables, Tea, and Spices*, CRC Press, ISBN 9780824705145.
- Chi-Tang Ho, Jen-Kun Lin and Fereidoon Shahidi. 2008. *Tea and Tea Products: Chemistry and Health-Promoting Properties*, CRC Press, ISBN 9780849380822.

- Kumar N, Khader JBMM, Rangaswami P., and Irulappan I. 2017. *Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants* (2nd Edition), Oxford & IBH Publishers, ISBN 9788120417762.
- Pruthi JS. 1993. *Major Spices of India Crop Management Postharvest Technology*, ICAR Publication, ISBN 1234567147556.
- Siddiqui MW. 2015. *Postharvest Biology and Technology of Horticultural Crops: Principles and Practices for Quality Maintenance*, CRC Press, ISBN 9781771880862.
- https://www.cabdirect.org/cabdirect/abstract/20006781145: https://www.springerprofessional.de/en/value-addition-in-flowers/4657550

Course Code: PHM 608
Course Title: Value Addition in Ornamental Crops
Credit Hours : (1+1)

I. Why this course ?

Ornamental crops provide better income from a unit area with higher profitability. The production of flower crops has increased significantly and there is huge demand for floricultural products in the world resulting in growing international flower trade. Value addition in floriculture increases the economic value and consumer appeal of any floral commodity. This course will be useful as a source of income generation.

II. Aim of the course

To acquaint the students about the scope and ways of value addition in ornamental crops.

The course is organized as follows:

No	Blocks	Units
1	Value addition of flowers	I Introduction II Value addition of flower crops III Neutraceuticals from petals
2	Floral arrangements and women empowerment	I Floral arrangements II Women empowerment

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III. Theory

Block 1: Value addition of flowers

Unit I: Introduction: Importance, opportunities and prospects of value addition in floriculture; national and global scenario; production and exports, supply chain management.

Unit II: Value addition of flower crops: Dry flower making including pot pourries, their uses and trade; extraction technology, uses, sources and trade in essential oils; aroma therapy; pigment and natural dyes extraction technology, sources, uses and trade.

Unit III: Neutraceuticals from petals: Pharmaceutical and neutraceutical compounds from flower crops; petal embedded hand made paper making and uses, preparation of products like gulkand, rose water, gulroghan, attar, pankhuri.

Block 2: Floral arrangements and women empowerment

Unit I: Floral arrangements: Floral craft including bouquets, garlands, flower arrangements, etc. tinting (artificial colouring) of flower crops;

Unit II: Women empowerment: Women empowerment through value added products making.

- Dry flower making including pot pourries; extraction technology, uses, sources and trade in essential oils;
- Pigment and natural dyes extraction technology;
- Pharmaceutical and neutraceutical compounds from flower crops;
- Preparation of products like *gulkand*, rose water*gulroghanattar, pankhuri*;
- Petal embedded handmade paper making;
- Floral craft including bouquets, garlands, flower arrangements, etc.*;*
- Tinting (artificial colouring) of flower crops.

IV. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Student presentation
- Group Work/ Seminars
- Product preparation and income generation assessment

V.Learning outcome

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

- Will be helpful in converting waste into wonder by making potpourris, greeting cards, etc.
- Students can give training to women and create a source of employment to rural women

VI. Suggested Reading

- Bhattacharjee SK and De LC. 2004. *Advances in Ornamental Horticulture* Vol. V, Pointer publishers, Jaipur.
- Gary L. McDaniel. 1989. *Floral design and arrangement*. A Reston Book. Prentice hall. New Jersey.
- Lauria A and Victor HR. 2001. *Floriculture – Fundamentals and Practices*. Agrobios. Lesniewicz Paul. 1994. *Bonsai in your home*. Sterling publishing Co, New York.
- Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios.

- Randhawa GS and Mukhopadhyay A. 2000. *Floriculture in India*, Allied publishers, India. Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hightech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi.
- Salunkhe K, Bhatt NR and Desai BB. 2004. *Postharvest biotechnology of flowers and ornamentalplants*. NayaProkash, Kolkata.

Websites

- http://www.vedamsbooks.com/no103218/user_forgot_pass.php
https://www.springerprofessional.de/en/value-addition-in-flowers/4657550
www.ihc2018.org/en/S29.html

Journals on Postharvest Management of Horticultural Crops

Sr. No.	Name of the Journal	ISSN No.
1.	*Annual Review of Food Science and Technology*	ISSN 19411421, 19411413
2.	*Comprehensive Reviews in Food Science and Food Safety*	ISSN 15414337
3.	*Trends in Food Science and Technology*	ISSN 09242244
4.	*Food Chemistry*	ISSN 03088146
5.	*Food Microbiology*	ISSN 10959998, 07400020
6.	*Postharvest Biology and Technology*	ISSN 09255214
7.	*Food Research International*	ISSN 09639969
8.	*Critical Reviews in Food Science and Nutrition*	ISSN 15497852, 10408398
9.	*Journal of Food Engineering*	ISSN 02608774
10.	*International Journal of Food Microbiology*	ISSN 01681605
11.	*Food Control*	ISSN 09567135
12.	*Innovative Food Science and Emerging Technologies*	ISSN 14668564
13.	*Food and Bioprocess Technology*	ISSN 19355130, 19355149
14.	*LWT-Food Science and Technology*	ISSN 10961127, 00236438
15.	*Journal of Functional Foods*	ISSN 17564646
16.	*Food Quality and Preference*	ISSN 09503293
17.	*Journal of Food Composition and Analysis*	ISSN 08891575, 10960481
18.	*Plant Foods for Human Nutrition*	ISSN 09219668, 15739104
19.	*Current Opinion in Food Science*	ISSN 22147993
20.	*Food Packaging and Shelf Life*	ISSN 22142894
21.	*Journal of the Science of Food and Agriculture*	ISSN 10970010, 00225142
22.	*International Journal of Food Science and Technology*	ISSN 13652621, 09505423
23.	*Journal of Food Science*	ISSN 00221147
24.	*Journal of Food Protection*	ISSN 0362028X

25.	*Phytochemical Analysis*	ISSN 09580344, 10991565
26.	*Food Reviews International*	ISSN 15256103, 87559129
27.	*European Food Research and Technology*	ISSN 14382377, 14382385
28.	*Biosystems Engineering*	ISSN 15375110, 15375129
29.	*Agribusiness*	ISSN 15206297, 07424477
30.	*Journal of Sensory Studies*	ISSN 08878250
31.	*Journal of Texture Studies*	ISSN 00224901
32.	*International Journal of Food Properties*	ISSN 10942912, 15322386
33.	*International Journal of Food Sciences and Nutrition*	ISSN 09637486, 14653478
34.	*Journal of Food Science and Technology*	ISSN 00221155
35.	*Advances in Food and Nutrition Research*	ISSN 10434526
36.	*Journal of Food Process Engineering*	ISSN 17454530, 01458876
37.	*British Food Journal*	ISSN 0007070X
38.	*Journal of Food Quality*	ISSN 01469428, 17454557
39.	*Food Science and Technology International*	ISSN 10820132
40.	*Irish Journal of Agricultural and Food Research*	ISSN 07916833, 20099029
41.	*Journal of Food Processing and Preservation*	ISSN 01458892
42.	*Stewart Postharvest Review*	ISSN 17459656
43.	*International Journal of Food Science*	ISSN 23145765, 23567015
44.	*Food Science and Technology*	ISSN 01012061, 1678457X
45.	*International Food Research Journal*	ISSN 19854668
46.	*International Food and Agribusiness Management Review*	ISSN 15592448, 10967508
47.	*Food Science and Technology Research*	ISSN 13446606
48.	*International Journal of Food Engineering*	ISSN 15563758, 21945764
49.	*Journal of Horticultural Research*	ISSN 23005009, 23533978
50.	*International Journal of Postharvest Technology and Innovation*	ISSN 17447550, 17447569
51.	*Food Technology*	ISSN 00156639
52.	*Open Nutraceuticals Journal*	ISSN 18763960
53.	*Advance Journal of Food Science and Technology*	ISSN 20424868, 20424876

MICROBIOLOGY

Course Title with Credit Load for M.Sc. in Microbiology

Sl. No.	Course Code	Course Title	Credit hours
1.	MICRO 501	Techniques in Microbiology	0+2
2.	MICRO 502*	Principles of Microbiology	3+1
3.	MICRO 503*	Microbial Physiology and Metabolism	3+1
4.	MICRO 504	Microbial Genetics	2+1
5.	MICRO 505*	Soil Microbiology	2+1
6.	MICRO 506	Microbial Biotechnology	2+1
7.	MICRO 507*	Food Microbiology	2+1
8.	MICRO 508	Bacteriophages	1+1
9.	MICRO 509	Environmental Microbiology	2+1
10.	MICRO 510	Industrial Microbiology	2+1
11.	MICRO 511	Biofertilizer Technology	2+1
12.	MICRO 512	Cyanobacterial and Algal Biotechnology	2+0

Course Title: **Techniques in Microbiology**

Course Code: **MICRO 501**

Credit Hours: **0+2**

Why this course?

The science of microbiology is the study of microorganisms and their activities. It is concerned with their form, structure, reproduction, physiology, metabolism and identification. It includes the study of their distribution in nature, their relationship to each other and their living things, their beneficial and detrimental effects on agriculture and the physical and chemical changes they make in their environment. In microbiology laboratories, some special equipment and apparatus are commonly used. Students of microbiology should have a general idea regarding their constructive features, operation, precaution for use, and also the maintenance of the equipment.

Aim of the course

This course aims to introduce various techniques and instrumentation methods required for the study of microorganisms. This course provides understating of techniques and methods of microscopy, spectroscopy, chromatography, and electrophoresis.

The course is organized as follows:

No.	Blocks	Units
1.	Technique in microbiology	1. Practicals include estimation of microbiological contents of samples like water, soil, air, etc. 2. Operation and care of microscopes 3. Preparation of smears and their morphological observation using a microscope 4. Performance of various staining techniques, study of biochemical activities, Identification of microorganisms, preparation of culture media etc.

Practicals

- Awareness of lab safety measures
- Study of general microbiological equipment, cleaning of glassware and apparatus for laboratory use
- Methods of sterilization used in the microbiology laboratory
- Use of simple techniques in the laboratory (Colorimetry, Centrifugation, electrophoresis and chromatography)
- Types of culture media
- Isolation techniques and direct microscopic count

- Environmental factors affecting bacterial growth: physical-chemical, temperature, pH, osmotic pressure, light (UV), and bacteriostatic agents. Bacteriology of air, water, and soil.
- Characteristics of important types of micro-organisms: major functional groups of bacteria, lactic acid, spore-forming, coliforms bacteria, fungi, yeast, and mold.
- Assessment of microbial quality of portable water.
- Working of a microscope

Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures
- Review of policy documents

Learning outcome

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

- Appreciate the scientific foundation of general microbiology and relate the key learning to the job of a microbiologist professional
- Utilise methods and tools for microbial agricultural development for the nation.
- Increase the probability of use of different microbial cultures for the benefits of agriculture production

Suggested Reading

- Roy A.K. 2010. *Laboratory Manual of Microbiology* (Practical Manual Series).
- Goldman E and Green LH. 2015. *Practical Handbook of Microbiology*. 3rd Edition. http/www. CRC press life science Microbiology
- Brock, T.D. 2008. *Biology of microorganisms* (Ed.) Madigan MT, Martinko J M, Dunlap P V,Clark D.P., 12th ed. Pearson, New Jersey.
- Pelczar, M.J. Jr., Chan, E.C.S. and Kreig, N.R. 1997. *Microbiology, Concepts and Application*, 5th edition, Tata McGraw Hill, New York.
- Prescott, L.M., Harley and Klein. 2002. *Microbiology* 5th Edition, Tata McGraw Hill, New York.
- Bhatia, M.S. 2009. *Principles of Microbiology*. Swastik Publishers., DeIhi.
- Madigan, M.T., J.M. Martinko, P.V. Dunlap and D.P. Clark. 2001. *Brock biology of Microorganism* 10th Ed. Pearson Education lnc, USA.
- Singh, U.S. and K. Kapoor 2010. *Introductory microbiology* Oxford Book Company., Jaipur
- Tortora, G.J., B.J. Funke and C.L. Case. 2010. *Microbiology: an introduction*.10th Ed. Benjamin Cummings., New York.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

Course Title: **Principles of Microbiology**

Course Code: **MICRO 502***

Credit Hours: **3+1**

Why this course?

Microbes has become a part and parcel of our lives This course is required for the future battle against infectious diseases worldwide, understanding the environmental importance of microbes and to exploit them for food production, biotechnological and industrial applications. Hence, this customized course.

Aim of the course

The main focus of our course is the potential of the organisms that cause disease and benefits in the society. You will also cover aspects of the biochemistry, physiology and genetics of microorganisms.

The course is organized as follows:

No.	Blocks	Units
1.	Scope and History of Microbiology and microscopy	1. Scope of microbiology and microscopy 2. History routes 3. Staining and microscopy
2.	Evolutionary link of prokaryotes	1. Phylogenetic classification 2. Methods of sequencing
3.	Microbial growth, characterization	1. Microbial growth and reproduction and regulation 2. Sterilization techniques 3. Nutritional requirements for microbial growth

Theory

Block 1: Scope and History of Microbiology and Microscopy

Unit 1: Scope of microbiology

Scope of microbiology, microbes and microbiologist. Emergence of Special Fields of Microbiology.

Unit 2: History Routes

The Germ Theory of Disease, Early Studies: Pasteur’s Further Contributions, Koch’s Contributions, Methods to control infections, spontaneous generation theory.

Unit 3: Staining and microscopy

Microscopy; Bright field, Dark field, Phase contrast, Confocal, Fluorescence, TEM, SEM – Working Principles and applications; Properties of light; Simple staining, Differential and special staining.

Block 2: Evolutionary Link of Prokaryotes

Unit1: Phylogenetic classification

Evolutionary relationship among prokaryotes. Prokaryotes and Eukaryotes, Phylogenetic and numerical taxonomy. Species concept.

Unit2: Methods of sequencing

Use of DNA and r-RNA sequencing in classifications. Techniques in identification of microbes through metagenomics

Block 3: Microbial Growth, Characterization And Regulation

Unit1: Microbial growth and reproduction

Major groups of microorganisms (Bacteria, fungi , actinomycetes and yeast), structure and function. Microbial growth and reproduction-communication, bacteria, yeast and virus growth, Replication, Cultivation methods, Normal micro flora of Human body; Immune response- specific and non-specific host resistance.

Unit 2: Sterilization techniques

Physical and chemical methods of sterilisation.

Unit 3: Nutritional requirements for microbial growth

Classification of microbes: electron, energy and carbon sources.

Practicals

- Working principles and handling of different types of microscopes – Bright and Dark field microscopy
- Working principles and handling of different types of microscope- SEM and TEM
- Methods of isolation from different environments – soil, water, milk and food
- Use of selective media for isolation
- Purification techniques of bacteria and fungi
- Enumeration and Quantification techniques
- Maintenance and preservation of cultures
- Assessment of microbial quality of portable water.
- Morphological characterization of Bacteria
- Morphological characterization of fungi
- Biochemical characterization of bacteria
- Biochemical characterization of fungus

Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review

- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures
- Review of policy documents

Learning outcome

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

- Knowledge on historical perspective of Microbiology
- Basic knowledge on different structure of microbes

Suggested Reading

- Brock TD. 2008. *Biology of microorganisms* (Ed.) Madigan MT, Martinko J M, Dunlap P V, Clark DP, 12th ed. Pearson, New Jersey.
- Pelczar MJ. Jr., Chan, ECS and Kreig NR. 1997. *Microbiology, Concepts and Application*, 5th edition, Tata McGraw Hill, New York.
- Prescott, L.M., Harley and Klein. 2002. *Microbiology* 5th Edition, Tata McGraw Hill, New York.
- Bhatia, M.S.2009. *Principles of Microbiology*. Swastik Publishers., DeIhi.
- Madigan, M. T., J. M. Martinko, P.V. Dunlap and D.P. Clark.2001. *Brock biology of Microorganism* 10th Ed. Pearson Education lnc, USA.
- Singh, U.S and K. Kapoor 2010. *Introductory microbiology* Oxford Book Company., Jaipur
- Tortora, G. J., B.J. Funke and C.L. Case. 2010. *Microbiology: an introduction*.10th Ed. Benjamin Cummings., New York
- Davis BD, Dulbecco R, Eisen HN and Ginsberg HS. 1990. *Microbiology* (4th edition). J.B.Lippincott company, Newyork.
- Alexopoulus CJ and C W. Mims. 1993. *Introductory Mycology* (3rd edition).Wiley Eastern Ltd, NewDelhi.
- Elizabeth Moore-Landecker. 1996. *Fundamentals of the fungi*. (4^{th} edition). Prentice Hall International, Inc, London.
- Heritage,J. Evans E.G.V. and Killington, R.A. 1996. *Introductory Microbiology*. Cambridge University Press.
- Webster J. 1993. Introduction to Fungi.(2nd edition).Cambridge University press, Cambridge.
- Prescott LM, Harley JP and Klein DA. 2006. Microbiology (7th edition) McGraw Hill, New York.
- Schaechter M and Leaderberg J. 2004. The Desk encyclopedia of Microbiology. Elseiver Academic press, California.
- Nester, E.W., Roberts, C.V. and Nester, M.T. 1995. *Microbiology: A human perspective*. IWOA, U.S.A.
- Pelczar Jr, M.J. Chan, E.C.S. and Kreig, N.R. 1993. *Microbiology*, Mc. Graw Hill. Inc, New York.

- Holt JG and Bergey DH. 1994. *Bergey's Manual of Determinative Bacteriology* (9th Edition), Williams and Wilkins, Baltimore.
- Mara D. and Horan N. 2003. *The Handbook of Water and waste water Microbiology*. Academic Press-An imprint of Elsevier.
- Madigan M T, Bender K S, Buckley HD, Sattley WM, Stahl DA 2017. *Brock Biology of Microorganisms* - 15th edition. Pearson Education, USA.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

II Course Title : Microbial Physiology and Metabolism
Course Code : MICRO 503*
Credit Hours : 3+1

Why this course?

Microbial physiology is defined as the study of how microbial cell structures, growth and metabolism function in living organisms. Microbial physiology is important in the field of metabolic engineering and also functional genomic. The study of diversity of microbial metabolic processes & their regulation, how microbes respond to environment stress and manipulation and the genetic control of these processes are essential for their potential applications of microbial process for the production of commercial products.

V. Aim of the course

Microorganisms have tremendous metabolic diversity hence it's intriguing to learn how these small creatures deal with different environmental conditions and either adopt themselves to it or convert it to favourable conditions by involving different physiological processes. The contents of this course will help students how microbes can grow on substrates other than glucose, their inorganic metabolism and photosynthesis and how do they respond to the changes in environment. It will elaborate the anaerobic respiration by variety of groups of microbes and nongenetic regulation at metabolic pathways.

The course is organized as follows:

o.	Blocks	Units
1.	Scope of microbial growth and physiology	1. Structure, function and biosynthesis of cellular components
2.	Pathways and their significance, Growth kinetics and nutritional classifications	1. Growth Kinetics, cell cycle, cell division, pathways and fermentation metabolism. 2. Growth and factors affecting growth and culture systems. 3. Nutritional classification and spore formation and germination
3.	Enzymes and microbial metabolisms	1. Kinetics and Mechanism of Enzymes 2. Microbial metabolism
4.	Synthesis of macromolecules	1. Biosynthesis of macromolecules

VI. Theory

Block 1: Scope of Microbial Growth and Physiology

Unit 1: Structure, function and biosynthesis of cellular components

Microbial nutrition – Chemical composition of microbial cell – Structure, and function of cell membrane in prokaryotes, archaea and fungi – Macro and Micro- nutrients and their physiological functions – Transport of solutes across the membrane

Block 2: Pathways and their Significance; Growth Kinetics and Nutritional Classifications

Unit 1: Growth Kinetics, cell cycle, cell division, pathways and fermentation metabolism

Microbial growth. Cell cycle and cell division. Bioenergetics - carbohydrate utilization via EMP, HMP, ED, TCA pathways, Aerobic and anaerobic respiration. Fermentative metabolism. Assimilation of nitrogen and sulphur - Oxygenic and anoxygenic photosynthesis - Mechanisms of carbon-dioxide fixation in prokaryotes. Ethanol, lactic acid, butanol, acetone and mixed acid fermentation. Fermentation of nitrogenous organic compounds ,Regulation of microbial metabolism.

Unit 2: Growth and factors affecting growth and culture systems

Effects of physical, chemical and other environmental factors on growth, Continuous culture, Diauxic growth and Synchronous culture. Method of growth measurement. Morphogenesis and cellular differentiation.

Unit 3: Nutritional classification and spore formation and germination

Metabolic diversity in photoautotrophs, photoheterotrophs, chemoautotrophs and chemoheterotrophs. Nutritional grouping/classification of microorganisms. Bacterial endospore-types, morphology, biochemistry and regulation of formation and germination

Block 3: Enzymes and Microbial Metabolisms

Unit 1: Kinetics and Mechanism of Enzymes

Enzyme kinetics: Michaelis Menten kinetics - mechanisms of inhibition of enzyme activity - coenzymes and prosthetic groups.

Unit 2: Microbial metabolism

Methods to determine free energy of biochemical reactions - high energy compounds. Microbial metabolism: generation of ATP, reducing power, development of proton gradient and biosynthesis of ATP.

Block 4: Synthesis of Macromolecules

Unit 1: Biosynthesis of macromolecules

Biosynthesis of macromolecules – Synthesis and assembly of cell wall components – Methods of studying biosynthesis

VII. Practicals

- Use of simple techniques in laboratory (Colorimetry, Centrifugation, electrophoresis and GLC, etc.).
- Determination of viable and total number of cells.
- Measurement of cell size.

- Gross cellular composition of microbial cell..
- Study of bacterial spores and factors affecting germination.
- Enzyme activity and kinetics – calculating Km and Vmax of enzyme.
- Demonstration of thermos-, meso-, and psychrophilic micro-organisms.
- Production and testing of inducible enzymes in bacteria.
- Sporulation and spore germination in bacteria.
- Protoplasts formation and regeneration.
- Estimation of generation time and specific growth rate for bacteria and yeast.
- Diauxic growth curve.
- Production of synchronous cells.
- Effect of chemicals and environmental factors on bacterial growth.
- Isolation and Identification of reserve food material (Glycogen/ polyphosphates, PHB) from bacteria (*Azotobacter*, *Bacillus megaterium*).
- Growth of microorganisms on various carbon and nitrogen sources.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures

IX. Learning outcome

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

- Knowledge about cell cycle and microbial pattern
- Growth and practical training on methods to determine microbialgrowth

X. Suggested Reading

- Moat, A. G. and J. W. Foster. 2002. *Microbial Physiology*. John Wiley & Sons, New York, USA. 11th ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- Madigan, M.T, J.M. Martinko and J. Parker. 2006. *Brock: Biology of Microorganisms*, 11th ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- White, D. 2007. *The Physiology and Biochemistry of Prokaryotes*, 3rd Edition. Oxford University Press.
- Downs, D. M. 2006. *Understanding microbial metabolism*. Annual Review of Microbiology 60, 533–559.
- Hosler *et al.* 2006. *Energy Transduction: Proton Transfer Through the Respiratory Complexes*. Annual Review of Biochemistry 75, 165-187.
- Okuno *et al.* 2008. *Correlation between the conformational states of F1-ATPase as determined from its crystal structure and single-molecule rotation*. PNAS 105(52): 20722-20727.
- Itoh et al (2004) Mechanically driven ATP synthesis by F1-ATPase. Nature 427, 465-468.
- Doelle HW. 1969. *Bacterial Metabolism*. Academic Press.

- Gottschalk G. 1979. *Bacterial Metabolism.* Springer Verlag.
- Nelson DL and Cox MM. 2017. *Lehninger, Principles of Biochemistry,* 4th Edition, W.H.Freeman & Company, 2004. (T1)
- Voet D and Voet JG. 2002. *Fundamentals of Biochemistry*, Upgrade Edition, Wiley.

Journals

- Journal of Bacteriology.
- Advances in Microbial Physiology.
- Soil Biology and Biochemistry.
- Journal of Applied Bacteriology.
- Applied and Environmental Microbiology.
- Microbiology.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.textbookofbacteriology.net
- https://www.e-education.psu.edu
- http://www.ncbi.nlm.nih.gov/pubmed/12050002
- http://www.journals.elsevier.com/bba-bioenergetics/
- http://www.bmb.leeds.ac.uk/illingworth/oxphos
- http://www.atpsynthase.info/
- https://ocw.um.edu.my/course/view.php?id=67
- https://mic.microbiologyresearch.org/content/journal/micro/ 10.1099/mic.0.037143-0

III Course Title : Microbial Genetics
Course Code : MICRO 504
Credit Hours : 2+1

Why this course?

Microbial Genetics has traditionally been a field of basic science research as microorganisms offer several features that facilitate the study of evolutionary process, understanding the genotype and its expression system. Students also hone their abilities to read, understand and critically evaluate research articles as well as improve presentation skills.

V. Aim of the course

This course is designed to provide an understanding of the fundamentals of genetic processes in prokaryotes and eukaryotes. The study of microbial genetics has provided much of the understanding of fundamental genetic processes for all organisms, especially through the use of *in vivo* and *in vitro* genetic tools.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to microbial genetics	1. Historical perspectives of microbial genetics 2. Genome of prokaryote, eukaryote (fungi) and virus

		3. Genetic elements - chemical structure andproperty, enzymes associated and replication 4. Extra-chromosomal DNA in bacteria andeukaryotic cells
2.	Gene expression and regulation	1. Introduction to Gene structure and expression 2. Regulation of gene expression
3.	3. Mutation, genetic recombination	1. Principles of mutation and types and sequencing 2. Mutagens and their mode of action 3. DNA damage – DNA repair mechanisms in bacteria 4. Genetic recombination in bacteria 5. Gene Sequencing

VI. Theory

Block 1: Introduction to Microbial Genetics

Unit 1: Historical perspectives of microbial genetics

Introduction to Microbial genetics; Historically important events and major contributions of scientists in the field of Microbial genetics; Terminologies employed in microbial genetics and definitions; Nucleic acid – overview DNA, RNA.

Unit 2: Genome of prokaryote, eukaryote (fungi) and virus

Bacterial genome Eukaryotic genome; Viral genome; Difference between prokaryotic and eukaryotic genome; Mechanisms and role of prokaryotic genome- an overview.

Unit 3: Genetic elements - chemical structure and property, enzymes associated and replication

Structure of DNA – A form, B form, Z form; RNA- tRNA, mRNA, rRNA; Role and Replication of DNA and RNA; Enzymes involved in Replication and its role.

Unit 4: Extra-chromosomal DNA in bacteria and eukaryotic cells

Plasmids, Mitochondrial DNA, Chloroplast DNA – structure and function.

Block 2: Gene Expression and Regulation

Unit 1: Introduction to gene structure and expression

Gene structure and expression, principles of operon, gene expression in prokaryote and eukaryotes, intron and exons, post transcriptional modifications.

Unit 2: Regulation of gene expression

Regulation of gene expression, negative expression (lac operon and trp operon), positive regulation (cAMP).

Block 3: Mutation, Genetic Recombination and Sequencing

Unit 1: Principles of mutation and types

Principles of mutation, spontaneous and induced mutation, different types of mutations, selection principles of mutants.

Unit 2: Mutagens and their mode of action

Mutagens and their mode of action, transposable elements and insertion sequences.

Unit 3: DNA damage - DNA repair mechanisms

DNA damage, DNA repair mechanisms in bacteria.

Unit 4: Genetic recombination in bacteria

Genetic recombination in bacteria, mechanisms of recombination, transformation, conjugation, transduction.

Unit 5: Gene sequencing

Gene cloning and gene sequencing. Impact of gene cloning, polymerase chain reaction, DNA sequencing, recombinant DNA technology.

VII. Practicals

- Isolation of genomic DNA from pure cultures of bacteria and fungi.
- Visualization of mega plasmids of bacteria.
- Isolation of bacterial plasmids and Plasmid curring.
- Qualitative and quantitative assay of DNA by spectrometry and gel-electrophoresis.
- Inducing mutation by chemicals, physical and biological agents.
- Transformation and selection of transformants.
- Amplification of gene of interest by PCR – cloning and expression.
- Isolation of metagenomic DNA from environmental samples.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group work in practical
- Field visit
- Case studies

IX. Learning outcome

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

- Identify and distinguish genetic regulatory mechanisms at different levels
- Plan basic experiments in Microbial genetics
- Describe and summarize experimental work in a correct way.

X. Suggested Reading

- Brown TA. 2001. *Gene Cloning and DNA Analysis: An Introduction*. Fourth Edition. Blackwell Science Inc., Oxford, UK.
- Levin B. 2002. *Gene VIII*. Oxford Univ. Press, New York. p.990.
- Maloy SR, Cronan JE, Freifelder D. 2008. *Microbial Genetics* - second edition. Narosa Publising house, New Delhi. p. 525.
- Omoto CK and Lurquin PF. 2004. *Genes and DNA: a beginner's guide to genetics and its applications*. Colambia University Press, USA.

- Sambrook J, Fritsch EF, Maniatis T. 2000. *Molecular Cloning: A laboratory Manuel*. Third Edition. Cold Spring Harbor Press, New York.
- Streips UN, Yasbin RE. 2006. *Modern Microbial Genetics*. Wiley – Liss. John Wiley & sons, Inc. Publication, NY.
- Birge EA. 1981. *Bacterial and Bacteriophage Genetics*. Springer Verlag.
- Gardner JE, Simmons MJ and Snustad DP. 1991. *Principles of Genetics*. John Wiley& Sons.
- Lewin B.1999. *Gene*. Vols. VI-IX. John Wiley & Sons.
- Maloy SR, Cronan JE and Friedfelder D. 2008. *Microbial Genetics*. Narosa.
- Scaife J, Leach D and Galizzi A 1985. *Genetics of Bacteria*. Academic Press. William Hayes 1981. *Genetics of Bacteria*. Academic Press.
- Strips UN, Yasbin RE *2006. *Modern Microbial Genetics*. Wiley-Liss, NY.

Websites

- http://highered.mcgraw-hill.com/sites/0072552980/student_view0/chapter9/
- http://highered.mcgrawhill.com/sites/0072835125/student_view0/animations.html
- http://cwx.prenhall.com/brock/
- http://www.cliffsnotes.com/sciences/biology/microbiology

•http://plato.acadiau.ca/courses/biol/Microbiology/home.HYPERLINK "http://plato.acadiau.ca/ courses/biol/Microbiology/home.html"html

- http://www.learner.org/courses/biology/index.html

Course Title : Soil Microbiology
Course Code : MICRO 505*
Credit Hours : 2+1

Why this Course?

Understanding the function of the soil ecosystem in relation to ever changing soil conditions is key to understanding the basic mechanisms of soil productivity. This is important in light of the urgency to change agricultural practices and also the problems of xenobiotic compounds in soils. The possible perturbations caused by pollution, intense agricultural practices or changing land use–are of major concern. The possibility of involvement of nonculturable or minute cell fractions requires innovative research using molecular biological techniques. Information on the effects of different root parts versus bulk soil is interesting. Role of microorganisms in biogeochemical cycles and their interactions decide the nutrients available to crops. The rhizosphere–the micro environment around plant roots houses intense biological, physical and geochemical activity distinguishing it from surrounding soil. Diversity, distributions, activities and interactions of innumerable organisms affect and are affected by availability of energy and nutrients, soil-water content and rhizosphere redox states. Soil food webs and nutrient cycling in agro ecosystems is of prime concern.

V. Aim of the course

- To help unlock and harness the potential of microorganisms in soil.
- To know the potential benefit of consortia of microorganisms to protect plants from different stresses.

- To study the role of microorganisms in the ecosystem functioning, nutrient cycling and biogeochemical processes including soil enzymes, through their metabolic activity and interactions.

The course is organized as follows:

No.	Blocks	Units
1.	Developments in soil Microbiology and Soil parameters	1. Historical prospective of soil microbiology. Factors affecting soil microflora 2. Ecology of soil microbiology
2.	Microbiology and Biochemistry of Plant parts	1. Plant parts and soil interface interaction
3.	Role of microorganisms in nutrient biocycle	1. Microbial transformations of various nutrients 2. Microbial degradation of organic matter 3. Microbial diversity 4. Role of microorganisms in biodegradation of xenobiotics and pesticides.

VI. Theory

Block 1: Developments in Soil Microbiology and Soil Parameters

Unit 1: Historical prospective of soil microbiology. Factors affecting soil microflora.

Landmarks in the history of soil microbiology. Abiotic factors (physical and chemical) affecting soil microflora as pH, chemicals, moisture, air, temperature etc.

Unit 2: Ecology of soil microbiology

Soil biota, Soil microbial ecology, types of organisms in different soils; Soil microbial biomass; Microbial interactions: unculturable soil biota.

Block 2: Microbiology and Biochemistry of Plant Parts

Unit 1: Plant parts and soil interface interaction

Microbiology and biochemistry of root-soil interface; phyllosphere, plant growth promoting rhizobacteria, soil enzyme activities and their importance.

Block 3: Role of Microorganisms in Nutrient Biocycle

Unit 1: Microbial transformation of various nutrients

Microbial transformations of nitrogen, phosphorus, sulphur, iron and manganese in soil. Siderophores and antimicrobials.

Unit 2: Microbial degradation of organic matter

Biochemical composition and biodegradation of soil organic matter and crop residues.

Unit 3: Microbial diversity

Endophytic microorganisms, Mycorrhizae, types and role in phosphate mobilization. Potassium releasing bacterium. Microbes in biotic and abiotic stress management.

Unit 4: Role of microorganisms in biodegradation of xenobiotics and pesticides

Biodegradation of pesticides, Organic wastes and their use for production of biogas and manures: Biotic factors in soil development.

VI. Practicals

- Determination of soil microbial population
- Determination of Soil microbial biomass
- Decomposition studies in soil based on the carbon dioxide evolution,
- Soil enzymes- Determination of dehydrogenase activity
- Measurement of important soil microbial processes such as ammonification, Nitrification, N2 fixation, S oxidation, P solubilization and mineralization of other micro nutrients
- Study of rhizosphere effect
- Microbial diversity of Endophytic microorganisms
- Observation of Mycorrhizae, types and Potassium releasing bacterium
- Effect of Microbes on biotic and abiotic stress management

VII. Teaching methods/activities

- Lectures. To use ppt and video clippings whenever necessary based on the topics that are hard to understand.
- The students must be assigned either in individual or in groups to identify the soils and crops grown and must get respective soil samples and plants for analyzing the microorganisms. They must subject the culture for various analysis depending upon the culture such a nitrogen fixing ability, phosphate solubilising property etc.
- Testing their efficiency through growth studies

VIII. Learning outcome

- Students will become familiar to the types of microbes in soil and their association with plants.
- The exclusive role of microorganisms in plant growth can be thoroughly understood.

IX. Suggested Reading

- Paul EA. 2015. *Soil Microbiology, Ecology and Biochemistry*. Elsevier
- Jan Dirk Van Elsas, Trevors JT and Elizabeth M.H. Wellington, 1997. *Modern Soil Microbiology*. Marcel Dekker, Inc.
- Paul EA. 2007. *Soil Microbiology and Biochemistry* 3rd Edition. Academic Press.
- Cardon ZG and Whitbeck JL. 2007. *The Rhizosphere An Ecological Perspective*. Academic Press.
- Schulz BJE, Boyle CJC and Sieber TN (Edrs). 2006. *Microbial Root Endophytes*. Pub Springer.
- Magesin R and Schinner F. (Edrs). 2005. *Manual of soil analysis monitoring and assessing soil Bioremediation*. Pub: Springer.

- Pinton R, Varanini Z and Nannipiers P. The Rhizosphere Biochemistry & organic substances at the soil-plant interface. Pub: CRC Press.
- Prasad TV. 2011. *A Text Book of Soil Microbiology*. Dominant Publishers & Distributors, New Delhi.
- Mukerji KG, Manoharachary C and Singh J. 2006. *Microbial activity n the Rhizosphere*. Pub: Springer.

Journals

- *European Journal of Soil biology.*
- *Canadian Journal of Microbiology*
- *Annual Review of Microbiology*
- *Journal of the Indian Society of Soil Science.*
- *Soil Biology and Biochemistry*
- *Applied soil ecology*

Websites

- www.nature.com
- www.microbiologysociety.org
- www.sare.org

I. Course Title : Microbial Biotechnology

II. Course Code : MICRO 506

III. Credit Hours : 2+1

IV. Why this course?

To give practical knowledge on fermentation and to develop fermentation for industrial application. Hence, this customised course.

V. Aim of the course

The aim is to teach students about industrially useful microorganisms and use of fermentor for the production of various primary and secondary metabolites The course is organized as follows:

No.	Blocks	Units
1.	Scope of Microbial Technology and Fermentation Metabolism	1. Microbial Biotechnology 2. Fermentation Metabolism 3. Fermenter/bioreactor design and operation 4. Fermentation system
2.	Recombinant products	1. Production of recombinant
3.	Microbial conversion and their product formation	1. Industrial production of beverages, acids and solvent 2. New tools and recent advances in microbial biotechnology

VI. Theory

Block 1: Scope of Microbial Technology and Fermentation Metabolism

Unit1: Microbial Biotechnology:

Introduction, Scopes, historical development, application and challenges.

Unit 2: Fermentation Metabolism

Fermentative metabolism, isolation, preservation screening and genetic improvement of industrially important microbes; Microbial growth kinetics.

Unit 3: Fermenter/bioreactor design and operation

Fermenters – types of fermenter, stirred tank reactor, bubble column reactor, airlift reactor, packed bed reactor, fluidized bed reactor and trickle bed reactor, agitation and aeration in a reactor, mass transfer. Foam formation and control.

Unit 4: Fermentation system

Types, Batch, Fed batch and continuous fermentation- multistage system. Solid state fermentation, Overproduction of primary and secondary metabolites e.g. amino acids, organic acids, alcohols, enzymes, organic solvents, antibiotics, etc.

Immobilization of enzymes; and cells; Scale-up principles; Down-stream processing, etc.

Block 2: Recombinant Products

Unit 1: Production of recombinant

Current advances in production of antibiotics, vaccines, and biocides; Steroid transformation; Bioprocess engineering; Production of recombinant DNA products, Immobilization techniques.

Block 3: Microbial Conversion and their Product Formation

Unit 1: Industrial production of beverages, acid and solvent

Production of alcohol (ethanol, wine and beer) and improvement by genetic engineering. Microbial production of acids (citric, acetic and gluconic acid) solvents (glycerol acetone and butanol) aminoacids (lysine and glutamic acid).

Unit 2: New tools and recent advances in microbial biotechnology

Concept of probiotics and applications of new tools of biotechnology for quality feed/food production; Microorganisms and proteins used in probiotics; Lactic acid bacteria as live vaccines; Bioconversion of substrates, anti-nutritional factors present in feeds; Microbial detoxification of aflatoxins; Microbial polysaccharides: fermentative production of xanthan gums. Bacterial bioplastics, genetic engineering of microorganisms for the production of poly-3 hydroxyalkanoates. Single cell protein, Bio-insecticides; Bio-fertilizers; Waste as source of energy/food Microbiologically produced food, colours, and flavours. Retting of flax. Recent advances in microbial biotechnology.

VII. Practicals

- Isolation and maintenance of industrially important microbes
- Production of alcohol
- Production of beer
- Production of citric acid

- Production of lactic acid
- Standardization of physical factors for the higher production of citric acid
- Production and assay of antibiotics
- Production of pullulan
- SCP production
- Study of bioreactors and their operation

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures

IX. Learning outcome

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

- Better knowledge on industrially important microbes
- Important downstreaming processes followed for product development

X. Suggested Reading

- Cruger W and Cruger A. 2004. *Biotechnology - A Textbook of Industrial Microbiology*. 2nd Ed. Panima.
- Ward OP. 1989. *Fermentation Biotechnology*. Prentice Hall.
- Wiseman A. 1983. *Principles of Biotechnology.* Chapman & Hall
- Peppler HJ and Perlman D.1979. *Microbial Technology*. 2nd Ed. Academic Press.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

Course Title : Food Microbiology
Course Code : MICRO 507*
Credit Hours : 2+1

Why this course?

Food Microbiology focuses on a wide variety of current research on microbes that have both beneficial and deleterious effects on the safety and quality of foods, and are thus a concern of public health.

This course, food microbiology focuses specifically on issues of food spoilage caused by the presence of food-borne pathogens. Students are instructed in methods of sanitation and preservation during food preparation and processing.

V. Aim of the course

To familiarize the students with recent advances in food microbiology including fermented foods, dairy, food preservation, detection of food- borne diseases, their control measures.

The course is organized as follows:

No.	Blocks	Units
1.	Historical Perspective and Scope of Microbiology in relation to food	1. Importance and significance of microorganisms in food 2. Factors of special significance in Food Microbiology 3. Microbial spoilage of different types of foods
2.	Fermentation and Food Preservation	1. Food fermentation methods 2. Preservatives and preservation methods
3.	Food safety and Quality	1. Advanced techniques in detecting food-borne Management Systems pathogens and toxins.

VI. Theory

Block 1: Historical Perspective and Scope of Microbiology in Relation to Food

Unit 1: Importance and significance of microorganisms in food

Introduction and scope; Food Microbiology Important microorganisms in food and their sources. Importance and significance of microorganisms in food.

Unit 2: Factors of special significance in Food Microbiology

Intrinsic and extrinsic factors influencing microbial growth in foods; Spores and their significance; Indicator organisms and Microbiological criteria.

Unit 3: Microbial spoilage of different types of foods

Microbial spoilage of meat, milk, fruits, vegetables and their products. Food-borne pathogens (bacteria, fungi and viruses) and intoxication.

Block 2: Fermentation and Food Preservation Methods

Unit 1: Food fermentation

Fermented dairy, vegetable, meat products.

Unit 2: Preservatives and preservation methods

Physical methods, chemical preservatives and natural antimicrobial compounds. Biologically based preservation systems. Foods for Specified Health Probiotic bacteria; Bifidus factor. Bacteriocins and their applications; Pre-, probiotics and symbiotics. Microbes as food single cell protein.

Block 3: Food Safety and Quality Management Systems

Unit 1: Advanced techniques in detecting food-borne pathogens and toxins

Food safety and Quality Management Systems- General principles of food safety risk management, Recent concerns on food safety- Safe food alternatives (Organic foods), Good agricultural Practices (GAP), Food Indicators of water and food safety and quality Advanced techniques in detecting food-borne pathogens and toxins. HACCP (Hurdle technology and Hazard analysis. Critical control point) CODEX, FSSAI (Food Safety and Standard Authority of India) systems in controlling microbiological hazards in foods. Food safety regulations

VII. Practicals

- Statutory, recommended and supplementary tests for microbiological analysis of various foods
- Infant foods, canned foods, milk and dairy products, eggs, meat, vegetables, fruits, cereals, surfaces, containers, normal, spoiled, processed, fermented food and water
- Testing of antimicrobial agents
- Analysis of water
- HACCP Plan
- Visit to Food processing Industries

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work in Practical
- Visit to Food processing Industries

IX. Learning outcome

With this course the students are expected to be able to learn

- Important microorganisms in food and their sources.
- Various Factors of special significance in Food Microbiology.
- Biologically based preservation systems of foods.
- Advanced techniques in detecting food-borne pathogens and toxins.

X. Suggested Reading

- Bibek Ray. 1996. *Fundamentals of Food Microbiology*. CRC Press.
- Frazier W.C. and Westhoff D.C. 1991. *Food Microbiology*. 3rd Ed. Tata McGraw Hill.
- George J Banwart. 1989. Basic Food Microbiology. AVI. James M Jay. 1987. Modern Food Microbiology. CBS.

- Peppler H.J. and Perlman D. 1979. *Microbial Technology*. 2nd Ed. Academic Press.
- Adams, M.R., and M. O. Moss 1996. *Food Microbiology*, New Age International (Rt) Ltd., New Delhi.
- Frazier, W.C. and D.C. Westhoff, 1988. *Food Microbiology* (Reprint 1995), Tata McGraw Hill Publishing Ltd., New Delhi.
- James M. Jay., Loessner, M.J. and Golden D.A. 2005. *Modern Food Microbiology*, Seventh edition.
- Verma, L.K. and Joshi, V.K. 2000. *Post Harvest Technology of Fruits and Vegetables*, Tata McGraw Hill Publication.
- Bhunia AK. 2008. *Foodborne Microbial Pathogens- Mechanisms and Pathogenesis, Food Science text Series,* Springer International, New York, USA.
- Benwart, G.J. 1987. *Basic Food Microbiology*, CBS Publishers & Distributors, New Delhi.
- Deak, T. and Beuchat LR. 1996. *Hand Book of Food Spoilage Yeasts*, CRC Press, New York.
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- Marriott, N.G. and Gravani R. B. 2006. *Principles of Food Sanitation, Food Science text Series*, Springer International, New York, USA.

Websites

- https://www.journals.elsevier.com/food-microbiology
- https://www.nature.com/subjects/food-microbiology
- https://www.frontiersin.org/journals/microbiology/sections/food-microbiology
- https://www.sciencedirect.com/journal/food-microbiology

Course Title : Bacteriophages
Course Code : MICRO 508
Credit Hours : 1+1

Why this Course?

Bacteriophages are viruses that infect and reproduce in bacteria. Phages are inherently highly specific towards bacterial hosts. This characteristic has both negative and positive aspects in that it is beneficial in terms of avoiding negative effects on the host microbiota and a hindrance when it comes to detection and elimination of the target pathogen Course is formulated to demonstrate the complete sequence of host parasite reactions and provide a model by which virus –host cell reactions can be postulated for infection in higher plants and animals.

V. Aim of the course

To familiarize the students about phages and phage- bacterial interactions. Bacteriophages have been of intense value in elucidating many biological phenomena, including those concerned with genetics.

The course is organized as follows:

No.	Blocks	Units
1.	Bacteriophages	1. Historical prospective of bacteriophages 2. Biological processes of phage bacterial interaction 3. Life cycle of bacteriophages 4. Biotechnological Genetic manipulation

VI. Theory

Block 1: Bacteriophages

Unit 1: Historical prospective of bacteriophages.

Historical developments and classification of bacteriophages.

Unit 2: Biological processes of phage bacterial interaction

Physiology, biochemistry, enzymology and molecular biology of phage- bacterial interactions.

Unit 3: Life cycle of bacteriophages.

Structure, functions and life cycles of P2 phage, Lambda phage, M13 phage, ÕX174 phage.

Unit 4: Biotechnological Genetic manipulation

Phages in the development of molecular biology and genetic engineering.

VII. Practicals

- Titration of phages and bacteria.
- Absorption of phages.
- Preparation of phage stocks.
- Isolation of new phages and phage resistant bacteria.
- One step growth curve, phage bursts.
- Induction of lambda.
- Complementation of T4*rII* mutantsetc.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work in Practical

IX. Learning outcome

With this course the students are expected to be able to learn

- About different phages and phage- bacterial interactions.
- Intensible value Bacteriophage in elucidating many biological phenomena, including those concerned with genetics.

- Development of molecular biology and genetic engineering

X. Suggested Reading

- Birge EA. 2000. *Bacterial and Bacteriophage Genetics.* Springer-Verlag. Mathew CK. 1972. *Bacteriophage Biochemistry*. Am. Chemical Soc.
- Mathew CK, Kutter EM, Mosig G & Berget P. 1988. *Bacteriophage T4*. Plenum Press.
- Nancy T and Trempy J. 2004. *Fundamental Bacterial Genetics*. Blackwell. Stent SG. 1963. *Molecular Biology of Bacterial Viruses*. WH Freeman and Co.
- Winkler J, Ruger W and Wackernagel W. 1979. *Bacterial, Phage and Molecular Genetics - An Experimental Course.* Narosa.
- Winkler U and Rugr W. 1984. *Bacteria, Phage and Molecular Genetics*. ALA.

Websites

- https://www.nature.com/scitable/definition/bacteriophage-phage-293
- https://www.phe-culturecollections.org.uk/news/nctc-news/the-rise-and-rise-ofbacteriophages.aspx
- https://www.khanacademy.org/science/biology/biology-of-viruses/virus-biology/a/ bacteriophages

I. Course Title : Environmental Microbiology

II. Course Code : MICRO 509

III. Credit Hours : 2+1

IV. Why this Course?

This course deals with the study of composition and physiology of microbial communities in the environment. Diversity of microbial populations and their important roles in air, water, soils and sediments. Microbial community ecology and interactions with plants and animals. Microbial communities control nutrient cycles and transformation of compounds. Deeper understanding about the beneficial and harmful effects of microbial communities in the environment will help, so this course has been mandated.

V. Aim of the course

The course is designed to introduce students to diverse microbial population and their important roles in environmental processes in air, water, soils and sediments.types of microorganisms found in the air, terrestrial and aquatic environments. Interaction of microbial communities with plants and animals. Geochemically and environmentally significant processes that are contributed by the activities of microorganisms. Methods that are used to identify and enumerate bacteria in natural environments and also how specific microbial activities. Impact of microbial degradation of organic contaminants and xenobiotics.

The course is organized as follows:

No.	Blocks	Units
1.	Microbial ecology	1. Scope of Environmental microbiology

		and Ecological Niche. 2. Microorganisms and their natural habitats 3. Extremophiles
2.	Microbial interaction	1. Biogeochemical cycles 2. Waste water and solid waste treatment
3.	Microbial upgradation in fossil fuels and interaction in rumen and gastrointestinal tract	

VI. Theory

Block 1: Microbial Ecology

Unit 1: Scope of Environmental microbiology and Ecological Niche

Scope of environmental microbiology, Microbial ecology: Microbial evolution and biodiversity – Ecological niches – Definitions, biotic and abiotic environment. Environmental segments. Composition and structure of environment. Concept of biosphere, communities and ecosystems. Ecosystem characteristics, structure and function. Food chains, food webs and trophic structures. Ecological pyramids.

Unit 2: Microorganisms and their natural habitats

Microorganisms and their natural habitats: Aeromicrobiology, Astrobiology, Methane and chlorates on Mars, terrestrial analogues. Biofilms and microbial mats, Aquatic ecosystems- Public Health Microbiology.

Unit 3: Extremophiles

Extremophiles: Definition and ecological aspects. Thermophiles, Xerophiles, Psychrophiles, Piezophiles, Alkaliphiles, Acidophiles-Halophiles and Barophiles. Environmental Distribution and Taxonomic Diversity, Physiology, Adaptive mechanisms, Enzymes, Applications.

Block 2: Microbial Interaction

Unit 1: Biogeochemical cycles

Biogeochemical cycling and its consequences. Global environmental problems.

Unit 2: Waste water and solid waste treatment

Microbiology of wastewater and solid waste treatment: - Waste-types-solid and liquid waste characterization, physical, chemical, biological, aerobic, anaerobic, primary, secondary and tertiary treatments. Anaerobic processes-Bioremediation of nuclear wastes. Bioconversion of Solid Waste and utilization as fertilizer. Bioaccumulation of heavy metal ions from industrial effluents. Biomining. Microbiology of degradation of xenobiotics in the environment, ecological considerations, decay behavior.

Unit 3: Microbial upgradation in fossil fuels and interaction in rumen and gastrointestinal tract.

Microbial upgradation of fossil fuels and coal gas. Microbial interaction in rumen and gastrointestinal tract.

VII. Practicals

- Determination of indices of pollution by measuring BOD/COD of different effluents.
- Microbial Analysis of natural waters.
- Quality control tests, waste treatment and anaerobic digestion;
- Demonstration of waste water treatment processes such as activated sludge processes, biofilter and fluidized bed process.
- Bacterial reduction of nitrate from ground waters.
- Isolation and purification of degradative plasmid of microbes growing in polluted environments.
- Recovery of toxic metal ions of an industrial effluent by immobilized cells.
- Utilization of microbial consortium for the treatment of solid waste [Municipal Solid Waste]
- Biotransformation of toxic metal ions into non-toxic metals ions.
- Microbial dye decolourization/adsorption.
- Biotrap based isolation of selective functional microbes.
- Thermophlic enzyme in biomass deconstructions.
- Halophilic microbes from salt lake-Pesticide degradation by microbes

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work in practical
- Field visit
- Case studies

IX. Learning outcome

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

- Appreciate the diverse microbial communities in environment and will be able to isolate and enumerate them from different environment.
- Realise the significance of microbial communities in biogeochemical cycles and their beneficial aspects to plants.
- Role of microorganism which are involved for bioremediation of harmful xenobiotic compounds.

X. Suggested Reading

- Campbell R. 1983. *Microbial Ecology*. Blackwell.
- Hawker LE & Linton AH. 1989. *Microorganisms Function, Form and Environment*. 2nd Ed. Edward Arnold.
- Richards BN. 1987. *Microbes of Terrestrial Ecosystem*. Longman.
- Mitchell R. 1992. *Environmental Microbiology*. John Wiley & Sons.
- Baker K.H. and Herson D.S. 1994. *Bioremediation.* McGraw Hill Inc., N.Y.

- Metcalf and Eddy HP. 2004. *Waste Water Engineering - Treatment, Disposal and Re-use.* Inc., Tata McGraw Hill, New Delhi.
- McEldowney S Hardman DJ and Waite S. 1993. *Pollution: Ecology and Biotreatment.* Longman Scientific Technical.
- Mitchell R, and GuJi-Dong. 2010. *Environmental Microbiology*. John V, Wiley Sons. Inc.
- Waste Water Microbiology 2nd Edition. Bitton. Chemistry and Ecotoxicology of pollution. Edited by Des. W. Connell, G.J. Miller. Wiley Interscience Publications.
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- Forster CF and John Wase DA. *Environmental Biotechnology*. Ellis Horwood Ltd. Publication.
- Trivedi RK. 1998. *Advances in Waste Water Treatment Technologies*. Volumes II and I Global Science Publication.
- Lawrence P, Wacekett C and Hershberger D. 2000. *Biocatalysis and Biodegradation: Microbial transformation of organic compounds*. ASM Publications.
- Hurst CJ. 2001. *A Manual of Environmental Microbiology*. 2nd Edition. ASM Publications.

Websites

- http://microbiology.ucsc.edu.
- http://www.asm.org

Course Title : Industrial Microbiology
Course Code : MICRO 510
Credit Hours : 2+1

IV. Why this Course?

The syllabus of industrial microbiology is oriented towards the industrial application of microorganisms and recent microbial products. After studying this course students will know the industrial aspects of microbiology.

V. Aim of the course

To expose the students to the commercial exploitation of microorganisms for production of useful products. Focus will be on understanding of the techniques involved and the application of microorganisms for agribusiness purpose.

The course is organized as follows:

No.	Blocks	Units
1.	Basics of Industrial Microbiology	1. Historical account of microbes in industrial Microbiology. 2. Fermented Microbial products.
2.	Bioplastics, Biopolymers & Biofuels	1. Biocontrol agents and Biopesticides 2. Industrial production of Bioplastics and biopolymers 3. Production of valuable products.

VI. Theory

Block 1: Basics of Industrial Microbiology

Unit 1: Historical account of microbes in industrial microbiology

Introduction to Industrial Microbiology. Sources and characters of industrially important microbes; their isolation, purification and maintenance. types of fermentation and fermenters. Microbial growth kinetics in batch, continuous and fed-batch fermentation process.

Unit 2: Fermented Microbial products

Bioreactors: Types and configuration. Microbiology and production of alcoholic beverages; Malt beverages, distilled beverages, wine and champagne; Commercial production of organic acids like acetic, lactic, citric, and gluconic acids, Commercial production of important amino acids (glutamic acid, lysine and tryptophan), vitamins (riboflavin and vitamin A), enzymes, antibiotics and single cell proteins.

Block 2: Bioplastics, Biopolymers and Biofuels

Unit 1: Biocontrol agents and Biopesticides

Biocontrol agents and Biopesticides: Biocontrol agents and their scope in control of plant diseases, nematodes and insect pests. Role of bioagents in sustainable agriculture.

Unit 2: Industrial production of Bioplastics and biopolymers

Introduction & industrial production of Bioplastics: Microorganisms involved in synthesis of biodegradable plastics and microbial pigments and biopolymers. Biosensors: Development of biosensors to detect food contamination and environment pollution. Biofuels: Production of ethanol, biogas and hydrogen from organic residues, fuels from algae; Mushroom cultivation.

Unit 3: Production of valuable products

Genetic engineering of microbes, Role of recombinant microbes in industrial sectors for enhanced production of valuable products. Mechanisms of pesticide degradation by microbes. Biomining: Coal, mineral and gas formation, prospecting for deposits of crude, oil and gas, recovery of minerals from low-grade ores.

VII. Practicals

- Isolation and purification of industrially important microbes (Bacteria, fungus and yeasts)
- Production of industrial compounds such as alcohol, beer, citric acid, lactic acid acetic acids gluconic acid and their recovery
- Demonstration of biogas production
- Production and assay of enzymes, organic acids and pigments
- Mass production of biocontrol agent

- Visit to industries

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work in Practical
- Field visit/Industries/University lab
- Case studies

IX. Learning outcome

After studying this course students will know and will be able to learn – The applied and industrial aspects of microbiology such as screening of microorganisms, strain improvement, microbial metabolites, fermented microbial products, microbial enzymes, Biofuels using microbes and microbial production of Biopolymers. The recent applications of the microbes for the human welfare.

X. Suggested Reading

- Sylvia DM, Fuhrmann JJ, Hartlly PT and Zuberer D. 2005. *Principles and Applications of Soil Microbiology*. 2nd Ed. Pearson Prentice Hall Edu.
- Waites, M.J., Morgan, N.L., Rockey, J.S. and Higton, G. (2002). *Industrial Microbiology: An Introduction.* Blackwell Science Publishers.
- Crueger W and Crueger A. *Biotechnology: A Text Book of Industrial Microbiology* Panima Publishing Corporation.
- Reed G. 1999. *Prescott and Dunn's Industrial Microbiology*. CBS Publishers.
- Demain AL. 2001. *Industrial Microbiology and Biotechnology* IInd Edition. ASM Press, Washington.
- Stanbury PF, Whitaker W and Hall SJ. 1997. *Principles of Fermentation Technology* Aditya Books (P) Ltd., New Delhi.
- Baltz RH, Davies JE and Demain AL. 2010. *Manual of Industrial Microbiology and Biotechnology*. 3rd Edition, ASM Press.
- Forciniti D. 2008. *Industrial Bioseparations: Principles and Practice*. 1st Edition, Wiley- Blackwell.
- OkaferN. 2007. *Modern Industrial Microbiology and Biotechnology,* Scientific Publishers, Enfield, USA.
- Nduka O and Benedict OC. 2018. *Modern Industrial Microbiology and Biotechnology,* Taylor and Francis 465p.
- El Mansi EMT, Bryce CFA, Dahhou A, Sanchez S, Demain AL, Allman AR. 2012. *Fermentation Microbiology and Biotechnology* 3rd Ed. CRC Press, Taylor and Francis, Boca Raton.
- Stanbury AF and Whitaker A. 1984. Principles of Fermentation Technology – Oxford Pergamon press New York.

- Moses V and Cape RE. 1991. *Biotechnology* - The Science and the Business Harwood Academic Publishers, USA.
- Casida LE Jr. 1989. *Industrial Microbiology* Wiley Eastern Ltd., N. Delhi.
- Miller BM and Litsky W. 1976. *Industrial Microbiology,* McGraw Hill Co.,New York 451p.
- Crueger W and Crueger A. 1984. *Biotechnology – a Text book of Industrial Microbiology*. Science Tech. Inc., Madison.
- Glazer AN and Nikaido HN. 1995. *Microbial Biotechnology: Fundamentals of Applied Microbiology*, W.H.Freeman Co., New York.
- Demain AL and Solomon MA. 1986. *Manual of Industrial Microbiology and Industrial Microbiology,* American Society of Microbiology, Washington.
- Atkinson B and Marituna F. 1983. *Biochemical Engineering and Biotechnology* Handbook, McMillian Publishers.
- Jones DG. 1983. *Exploitation of Microorganisms*. Chapman & Hall, Oxford.
- Peppler HJ and Perlman D. 1979. Microbial technology Vol.1 Fermentation Technology, Vol.2, Academic Press.
- Rehm HJ and Reed G. 1995. *Biotechnology, a Comprehensive Treatise*, 8 Vols. (Reference Book) Verlag Chemie,Wienheim. Also refer Second edition, 12 vols,1995 (Rehm,H.J.: Reed, G.: Puhler,A; Stadler, P Eds)
- Moo-Young Y. 1985. *Comprehensive Biotechnology*- 5 vols. (Reference Book) Pergamon Press, Oxford.
- Arora DK. 1992. *Handbook of Applied Mycology* – 5 Vols. (Reference Book) Marcel Dekker, New York.
- Glick BR and Pasternak JJ. 2003. *Molecular Biotechnology-principles and applications of recombinant* DNA, ASM press, Washington,760 pp.
- Also consult latest issues of:
- Advances in Applied Microbiology, Biotechnology Advances,
- Biotechnology & Genetic Engineering Reviews,Advances in Biochemical Engineering & Biotechnology, Advances in Microbial Physiology

Websites

- https://www.biomerieux.com/en/industrial-microbiological-control-0
- https://icar.org.in/content/food-and-industrial-microbiology

Course Title : Biofertilizer Technology

Course Code : MICRO 511

Credit Hours : 2+1

IV. Why this Course?

The exploitation of beneficial microbes as a biofertilizer is of prime importance in agriculture sector for their potential role in food safety and sustainable crop production. There is wide gap between nutrient removal and supplies. There is increase in cost of fertilizers due to deplete in the feed stock fossil fuels besides growing concern of environmental hazards due to chemical fertilizers. It is essential to exploit Biofertilizers having functional traits for enhancing plant growth and productivity, nutrient profile, plant defense and protection with special emphasis to its function to trigger various growth- and defense-related genes in signaling network of cellular pathways to cause cellular response and thereby crop improvement. The syllabus Biofertilizers technology is oriented towards application of biofertilizer to trap atmospheric nitrogen to the soil and convert them into plant usable forms. They also convert the insoluble phosphate forms into plant available forms. They stimulate root growth by producing some hormones and antimetabolites. Improved Plants.

V. Aim of the course

To familiarize the students and farmers with mass scale production of different agriculturally important microorganisms which are being used as biofertilizers for maintaining the soil and plant health for sustaining crop productivity and their importance in organic farming.

The course is organized as follows:

No.	Blocks	Units
1.	Agriculturally important beneficial microorganisms	1. Agriculturally important beneficial nitrogen fixing microorganisms. 2. Agriculturally important beneficial microorganisms related to phosphorous, potassium, Sulphur and Zinc nutrition 3. Agriculturally important beneficial microorganisms having plant growth promoting rhizobacteria 4. Agriculturally important biocontrol microbial inoculants 5. Economics of biofertilizer production.
2.	Production of Biofertilizer	1. Production and quality control of biofertilizer

VI. Theory

Block 1: Agriculture Important Beneficial Microorganisms

Unit1: Agriculturally important beneficial nitrogen fixing microorganisms.

Different agriculturally important beneficial microorganisms: Chemical Vs Biofertilizers: Current Scenario in biofertilizer technology in world-In India-List of biofertilizers-their applications in agriculture. Brief introduction about Agriculturally beneficial microorganisms (free living, symbiotic (rhizobial, actinorhizal), associative and endophytic nitrogen fixers including phosphobacteria, cyanobacteria, their types and importance taxonomic classification, Nitrogen fixing biofertilizers: nodule formation, competitiveness and quantification of N2 fixed and their use. Mechanism of phosphorous solubilizationby photobacteria. BIS standards of biofertilizers. Application of nanotechnology in bioinoculant production.

Unit 2: **Agriculturally important beneficial microorganisms related to phosphorous, potassium, Sulphur and Zinc nutrition**

Different agriculturally important beneficial microorganisms: phosphate solubilizing bacteria and fungi, including mycorrhiza; Mechanism of phosphorous solubilization by phosphobacteria. Bacteria for potassium, Sulphur and Zinc nutrition.

Unit 3: **Agriculturally important beneficial microorganisms having plant growth promoting rhizobacteria.**

Different agriculturally important beneficial microorganisms: plant growth promoting rhizobacteria. FCO norms and biofertilizer production and usage at national and international levels

Unit 4: **Agriculturally important biocontrol microbial inoculants**

Different agriculturally important beneficial microorganisms: Biocontrol microbial inoculants. Requirements for establishing bioinoculants production unit. Economics of biofertilizers production. Constraints in biofertilizers production and usage

Unit 5: **Economics of biofertilizer production**

Different agriculturally important beneficial microorganisms for recycling of organic waste and compositing, bioremediators and other related microbes.

Block 2: **Production of Biofertilizer**

Unit 1: **Production and quality control of biofertilizer**

Different agriculturally important beneficial microorganisms - selection, establishment, competitiveness, crop productivity, soil & plant health, mass scale production and quality control of bio inoculants. Biofertilizer inoculation and microbial communities in the soil. Different formulations of biofertilizers. Advantages and limitations of Liquid formulations.

VII. Practicals

- Isolation of phosphate solubilizing microorganisms.
- Isolation of efficient microorganisms,
- Determination of beneficial properties in important bacteria to be used as biofertilizer, Nitrogen fixing activity, indole acetic acid (IAA), siderophore production etc,
- Bioinoculant mass production and quality control.
- Population dynamics in broth and carrier materials during storage.
- Development of cultures from starter.
- Preparation of broth for large scale cultivation in fermenter/ large containers. Inoculation and development of culture.
- Mass production of carrier based and liquid biofertilizers. Mass production ofimportant two or three biocontrolagents (*Trichoderma viride*, *Pseudomonas fluorescens* and *Metarhizium anisopliae*).
- Form, dose and method of application.
- Mass production of AM fungi in pot and root organ culture.
- Quality control and BIS standards.

- Mass production of Azolla and BGA.
- Visit to a biofertilizer production plant

VIII. Teaching methods/activities

- o Lecture
- o Assignment (Reading/Writing)
- o Publication Review
- o Student presentation
- o Group discussion
- o Case Analysis and case studies
- o Guest Lectures
- o Review of policy documents

IX. Learning outcome

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

- o Agriculturally important beneficial microorganisms for fixation of various important elements and compounds.
- o Biofertilizer production and usage at national and international levels.
- o Requirements for establishing bioinoculants production unit, economics (solid liquid carrier) production, constraints in biofertilizers production and usage.
- o A complete exposure to all kinds of agriculture important biofertilizers along with their functions and properties,
- o Helps to develop as entrepreneur.

X. Suggested Reading

Books

- Alexander M. 1977. *Soil Microbiology*. John Wiley.
- Bergerson FJ. 1980. *Methods for Evaluating Biological NitrogenFixation.* John Wiley & Sons.
- Sylvia DM, Fuhrmann JJ, Hartlly PT and Zuberer D. 2005. *Principles and Applications of Soil Microbiology.* 2nd Ed. Pearson Prentice Hall Edu.
- Van Elsas JD, Trevors JT and Wellington EMH. 1997. *Modern Soil Microbiology*. CRC Press.
- Panwar JDS and Jain AK. 2016. *Organic farming scope and use of biofertilizers.* Pub: NIPA, New Delhi.
- Gaur AC. 2010. *Biofertilizers in Sustainable Agriculture*, ICAR, New Delhi.
- Chanda P and Srivathsa RSH. 2005. *Liquid Biofertilizers*. Ministry of Agriculture Department of Agriculture & Cooperation, GOI.
- DeshMukh AM, Khobragade RM and Dixit PP. 2007. *Handbook of Biofertilizers & Biopesticides*. Oxford Book Company, Jaipur, India.
- Gupta RP, Kalia A and Kapoor S. 2007. *Bioinoculants a Step towards Sustainable Agriculture,*.NIPA, New Delhi.

- Somani LL, Shilkar P and Shilpkar D. 2011. *Biofertilizers Commercial Production Technology & Quality Control*. AgroPublishing Acadamy, Udaipur.
- Srivastava HS and Singh RP. 1995. *Nitrogen nutrition in higher plants*. Associated Publishing Company, New Delhi.
- Kannaiyan S and Kumar K. 2005. *Azollabiofertiliser for sustainable Rice Production*. Daya Publishing House, Delhi.
- Kannaiyan S, Kumar K and Govindarajan K. 2010. *Biofertilizer Technology*. Scientific Publishers (India), Jodhpur.
- Vora MS, Shelat HN and Vyas RV. 2013. *Handbook of Biofertilizers & Microbial Pesticides*.
- Chanda JK. 2008. *Biofertilizer Statistics 2006-07*. The fertilizer Association of India, New Delhi.

Journals

- *Journal of Biofertilizer& Biopesticides*
- *Journal of Botanical Sciences*

Websites

- Biofertilizer in organic Agriculture (www.Journalphytology.com)
- Microbial biofertilizers (www.Boffinaccess.com)
- Biofertilizer as a prospective input for sustainable agriculture in India. http://www.krishisewa.com/articles/organic-agriculture/115-biofertilizers.html
- Handbook of Microbial Biofertilizers M. K. Rai, PhD Editor Pub: Food Products Press, NY.
- Bio fertilisers https://www.worldcat.org/search?q=biofertilisers&fq=dt%3Abks&dblist=638&qt=sort&se= yr&sd=desc&qt=sort_yr_desc

Course Title : Cyanobacterial and Algal Biotechnology

Course Code : MICRO 512

Credit Hours : 2+0

Why this Course?

Cyanobacteria and algal biomass contribute major role in carbon cycle in turn influencing the climate. The blooms of cyanobacteria and algae in different ecosystems is worth exploiting due to their wide biodiversity. They play an important role in agriculture by contributing to the fertility of soil in terms of biomass, biofertilizer, and act as herbicides, insecticides and in bioremediation. Their physiological and biochemical properties disclose their significant potential for colorants, polysaccharides, pharmaceutical & nutraceutical compounds, and valuable biomolecules of industrial importance. With the population explosion and scarcity of land, these can provide better feed stock due to their high protein content, easy cultivation, and versatile growth and easy to harvest. It is challenging for designing bioreactor and utilizes waste waters for growing and harvesting cyanobacteria and algae for these purposes. They are capable of producing and accumulating lipids which can be the source for biodiesel in future. This course will help the student to understand taxonomy and molecular biology methods of cyanobacteria. The course will give knowledge on cyanobacterial and algal fuels,

V. Aim of the course

The aim is to give exposure on the potential applications of cyanobacteria and algae in Agriculture, Industry and Environment; to inculcate knowledge on algal mass production techniques and their valuable products of commercial importance and to introduce the R&D and entrepreneurial opportunities algae. Students will learn about biodiversity of cyanobacteria and their classification**, t**he biotechnological applications in agriculture – biofertilizers, biocontrol, bioenergy and bioprocessing, their applications in pharmaceuticals, production of antioxidative enzymes and pigments, as source of food, etc.

The course is organized as follows:

No.	Blocks	Units
1.	Importance of cyanobacteria and algae	1. Ecology and evolution of algae and cyanobacteria
2.	Physiology and culturing of cyanobacteria and algae	1. Algal pigments, storage products. 2. Metabolism of carbon and nitrogen. 3. Culturing methods.
3.	Role of cyanobacteria and algae in agriculture and their products of industrial importance	1. Importance as fuels, neutraceuticals and industrial importance 2. Role of algae related to environment.

VI. Theory

Block 1: Importance of Cyanobacteria and Algae

Unit 1: Ecology and evolution of algae and cyanobacteria

Introduction to cyanobacteria and algae. Definition, occurrence and distribution, thallus structure, reproduction, life cycles, origin and evolution of cyanobacteria, molecular evolution; role of algae in evolution of land plants and horizontal transfer of genes. Brief classification of algae: different classes, occurrence and distribution.

Block 2: Physiology and Culturing of Cyanobacteria and Algae

Unit 1: Algal pigments, storage products.

Algal pigments, storage products, physiology and metabolism including photosynthesis.

Unit 2: Metabolism of carbon and nitrogen

Ecology of algae –primary colonizers and cycling in soil and water. Cellular differentiation and nitrogen fixation, nitrogen metabolism carbon metabolism.

Unit 3: Culturing methods

Algal culturing and cultivation. Culture types, culture conditions, culture vessels, culture media, sterilization, culture methods, synchronous cultures, photobioreactors, algal density and growth, seaweed cultivation.

Block 3: **Role of Cyanobacteria and Algae in Agriculture and their Products of Industrial Importance**

Unit 1: **Importance as fuels, neutraceuticals and industrial importance.**

Cyanobacterial and algal fuels, Fine chemicals (restriction enzymes etc.) and nutraceuticals from algae; UV absorbing pigments, Industrial products from macroalgae - seaweed biotechnology, sustainable aquaculture. Ecology of algae- distribution in soil and water; primary colonizers, carbon sequestration and cycling in soil and water. Cellular differentiation and nitrogen fixation, nitrogen metabolism.

Unit 2: **Role of algae related to environment.**

Algae in pollution control - as pollution indicators, eutrophication agents and role in Bioremediation and reclamation of problem soils. Cyanobacterial and algal toxins, allelopathic interactions, Algae in global warming and environmental sustainability. Cyanobacteria and selected microalgae in agriculture – biofertilizers & algalization; soil conditioners; reclamation of problem soils.

VII. Teaching methods/activities

- Lecture
- Assignment (reading/writing)
- Publication review
- Student presentation
- Group discussion
- Case analysis and case studies
- Guest lectures

VIII. Learning outcome

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

- Types of cyanobacteria and algae along with their physiological and biochemical properties that provides base for selection for further exploitation of industrial use.
- Algal culturing and cultivation. Culture types, culture conditions, synchronous cultures, photobioreactors, algal density and growth, seaweed cultivation.
- Production of cyanobacterial and algal fuels
- Industrial products from macro algae – seaweed biotechnology, sustainable aquaculture.
- Ecology of algae – distribution in soil and water; primary colonizers, carbon sequestration and cycling in soil and water.

IX. Suggested Reading

- Ahluwalia AS. 2003. *Phycology: Principles, Processes and Applications*. Daya Publ.

- Barsanti L and Gualtieri P. 2006. *Algae: Anatomy, Biochemistry and Biotechnology*. Taylor & Francis, CRC Press.
- Carr NG and Whitton BA. 1982. *The Biology of Cyanobacteria*. Blackwell.
- Herrero A and Flores E. 2008. *The Cyanobacteria Molecular Biology,Genomics and Evolution*. Calster Academic Press
- Kumar HD. 2005. *Introductory Phycology.* East West Press. Linda E Graham & Lee W Wilcox. 2000. *Algae*. Prentice Hall.
- Andersen RA. 2005. *Algal Culturing Techniques.* Academic Press.
- Venkataraman LV and Becker EW. 1985. *Biotechnology and Utilization of Algae: the Indian Experience*. DST.
- Das MK. 2010. *Algal Biotechnology*. Daya Publishing House.
- Tiwari. 2014. *Cyanobacteria: Nature, Potentias and Applications*. Daya Publishing House.
- Khattar JIS, Singh DP, Kaur G. 2009. *Algal Biology and Biotechnology*. I.K. International Publishing House Pvt. Ltd.
- Bhatnagar SK, Saxena A, Kraan S. 2011. *Alga Biofuels*. Stadium Press (India) Pvt. Ltd.
- Sahoo D and Kaushik BD. 2012. *Algal Biotehcnolgoy and Environment*. I.K. International Publishing HousePvt. Ltd.

Journals

- *Journal of Phycology*
- *Journal of Applied Phycology*
- *Frontiers in Microbiology*

Websites

- Cyanbacterial and algal Biotechnology
- https://www.worldcat.org/search?q=cyanobacterial+and+algal+biotechnology &qt=results_ page#%2528x0%253Abook%2Bx4%253Aprintbook%2529format
- www.cyanosite.bio.purdue.edu
- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.bbsrc.ac.uk/organisation/policies/reviews/scientific-areas/1107-algal-research. aspx
- http://asulightworks.com/resources/videos/arizona-center-algae-technology-and-innovation. Html

Course Title with Credit Load for Ph.D in Microbiology

Sl. No.	Course Code	Course Title	Credit hours
1.	MICRO 601*	Improvements in fermentation Technology	2+1
2.	MICRO 602	Microbial physiology and regulation	2+0
3.	MICRO 603*	Recent development in soil microbiology	2+0
4.	MICRO 604	Recent approaches in environmental microbiology	2+0
5.	MICRO 605*	Plant microbe interactions	2+1
6.	MICRO 691	Doctoral seminar I	1+0
7.	MICRO 692	Doctoral seminar II	1+0
8.	MICRO 699	Doctoral Research	75

*Core Courses

I. Course Title : Improvements in Fermentation Technology

II. Course Code : MICRO 601*

III. Credit Hours : 2+1

IV. Why this Course?

This course aims to introduce technological advancement of fermentation and bioprocess for industrial applications. Microorganisms are capable of growing on a wide range of substrates and can produce a remarkable spectrum of products. This course will enlighten the students on basics of fermentation, metabolic engineering, fermenter design and downstream processing. The economics of industrial products are introduced to understand commercialization of microbial products.

V. Aim of the course

The aim is to teach students regarding fermentation industry using industrially useful microorganisms including yeast technology. To introduce the students to broad coverage of a diverse field of fermentation technology, provide an understanding of the exploitation of microorganisms in the manufacture of bio products and provide the students with skill in operation of fermenter.

The course is organized as follows:

No.	Blocks	Units
1.	Rise of Fermentation Technology	1. Development in Fermentation 2. Types of Fermenters
2.	Fermenter	1. Component of fermenter and use
3.	Fermentation process	1. Types of Fermentation
4	Recombinant Strategies Followed	1. Strategies for isolation of industrially important microbes

VI. Theory

Block 1: Rise of Fermentation Technology

Unit 1: Development in Fermentation

Definition of fermentation – rise of fermentation technology – current trends in fermentation industry – scope and importance of fermentation technology.

Unit 2: Types of fermenters

Continuous, batch and fed batch culture –anaerobic fermentation - range of fermentation process – microbial growth cycle – diauxic growth – growth kinetics – substrate uptake kinetics (Jacob and Monod) - primary and secondary metabolites – future prospects of fermentation microbiology.

Block 2: Fermenter

Unit 1: Components of fermenter and use

Peripheral parts and accessories – alternative vessel designs – containment in fermentation – fermenter preparation and use - aeration and agitation – instrumentation and control – biosensors in monitoring – computer applications in fermentation technology.

Block 3: Fermentation Process

Unit 1: Types of Fermentation

Solid state and submerged fermentation – acidic/alcoholic fermentation – recovery of product – effluent treatment – Economics of fermentation

Block 4: Recombinant Strategies Followed

Unit 1: Strategies for isolation of industrially important microbes

New strategies for isolation of industrially important microbes and their genetic manipulations; Antibiotic fermentation research; steroid transformation; Yeast technology – classification, genetics, strain improvement for brewing, baking and distilleries.

VII. Practicals

- Studying the various components of fermenter
- Exposure to different types of fermenter
- Sterilization and operating procedures
- Designing the production culture medium
- Isolation and purification of industrially important microbes
- Genetic manipulations in microbes
- Fermentation by improved strains of yeast for production of alcohol
- Microbial production of enzymes by solid state fermentation
- Microbial production of important antibiotics
- Bioremediation of industrial effluents

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies

- o Guest Lectures

IX. Learning outcome

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

- o Students should have an understanding of the variety of fermentation and subsequent processing approaches available for the manufacture of biological products and the design and operation of these systems.

X. Suggested Reading

- Stanbury PF, Whitaker A and Hall SJ. *Principles of fermentation technology*, Second edition
- Patel AH. *Industrial Microbiology*
- El Mansi EMT and Bryce CFA. *Fermentation Microbiology and Biotechnology*
- Srivastava ML. *Fermentation Technology*
- Singh T and Purohit SS. *Fermentation Technology*
- El Mansi EMT, Bryce CFA, Demain AL and Allman AR. *Fermentation Technology – Microbiology and Biotechnology*
- Peppler HJ and Perlman D. 1979. *Microbial Technology*. 2nd Ed. Academic Press.
- Reed G. 1987. *Presscott& Dunn's Industrial Microbiology.* 4th Ed. CBS.
- Stanbury PF and Whitaker A. 1987. *Principles of Fermentation Technology*. Pergamon Press.
- Wiseman A. 1983. *Principles of Biotechnology.* Chapman & Hall.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.scribd.com/doc/46151150/Fermentation-Technology
- http://www.chalmers.se/en/areas-of-advance/lifescience/research/Pages/Fermentation-Technology.aspx

Course Title : Microbial Physiology and Regulation

Course Code : MICRO 602

III. Credit Hours: 2+0

IV. Why this Course?

Microorganisms have tremendous metabolic diversity hence it's intriguing to learn how these small creatures deal with different environmental conditions and either adopt themselves to it or convert it to favorable conditions by involving different physiological processes. The contents of this course will help students how microbes can grow on substrates other than glucose, their inorganic metabolism and biosynthesis and how do they respond to the changes in environment.

V. Aim of the course

To acquaint students with current topics in molecular microbiology. Course imparts thorough knowledge about the synthesis of biomolecules in microorganisms by various pathways and their regulation.

The course is organized as follows:

No.	Blocks	Units
1.	Historical evaluation of microbial	1. Molecular aspects of various cell component physiology
2.	Regulation and pathways	1. Regulatory Pathways 2. Regulatory control
3.	Current topics	

VI. Theory

Block 1: Historical Evaluation of Microbial Physiology

Unit 1: Molecular aspects of various cell component

Origin, evolution, structure, function and molecular aspects of various cell components. Differentiation in bacteria, slime molds, yeasts. Molecular biology of bioluminescence, bacterial virulence. Heat shock response. Extracellular protein secretion in bacteria.

Block 2: Regulation and Pathways

Unit 1: Regulatory Pathways

Regulation of initiation, termination and anti-termination of transcription. Global regulation and differentiation by sigma factor. Regulatory controls in bacteria - inducible and biosynthetic pathways. Oxidative stress control. Fermentative and respiratory regulatory pathways.

Unit 2: Regulatory control

Ribosomal RNA and ribosomal proteins regulation under stress condition. Specific regulatory systems; SOS regulatory control; Antisense RNA regulation of gene expression. Biosynthesis of micromolecules (Nucleotides and Aminoacids) macromolecules (DNA, RNA, Proteins) Global nitrogen control and regulation of nitrogen fixation.

Unit 3: Current topics

Topics of current interest in Molecular microbiology and regulatory systems.

VII. Teaching methods/activities

- Class room Lecture
- Assignment (Reading/Writing)
- Student presentation
- Seminar presentation by students

VIII. Learning outcome

With this course, the students are expected to be able to learn

- Current topics in molecular microbiology.

- o Thorough knowledge about the synthesis of biomolecules in microorganisms by various pathways and their regulation.
- o About the synthesis of biomolecules in microorganisms by various pathways and their regulation.

IX. Suggested Reading

Websites

- https://www.frontiersin.org/journals/microbiology/sections/microbial-physiology-and metabolism
- https://www.sciencedirect.com/bookseries/advances-in-microbial-physiology
- https://www.researchgate.net/journal/0065-2911_Advances_in_Microbial_Physiology
- https://bmb.psu.edu/undergraduate/courses/course-archive/2016/fall-2016/microbiologymicrb/ micrb-401-fall-2016/micrb-401-microbial-physiology-and-structure
- Selected articles from journals.

Course Title : Recent Developments In soil microbiology

Course Code : MICRO 603*

Credit Hours : 2+0

Why this Course?

Directly or indirectly the waste of human and other animals, their bodies, and the tissues of plants are dumped onto or buried in the soil. It is the microbes that make these changes –the conversion of organic matter in to simple organic substances that provide the nutrient material for the plant and agriculture world. Thus microorganisms play a vital role in maintaining life on earth. The prerequisite for this class is SOIL. To be completely prepared for this class a course taken in Microbiology is very useful.

V. Aim of the course

To make students learn the latest trends in soil microbiology like diversity, biological control and bioremediation.

The course is organized as follows:

No.	Blocks	Units
1.	Recent developments in soil	1. Ecology and microorganisms diversity microbiology
2.	Role of microorganisms in soil	
3.	Bioremediation	

VI. Theory

Block 1: Recent Developments in Soil Microbiology

Unit 1: Ecology and microorganisms diversity

Molecular ecology and biodiversity of soil microorganisms; Survival and dispersal of microorganisms. Interaction between agricultural chemicals, pollutants and soil microorganism

Unit 2: Role of microorganisms in soil

Successions and transformation of organic matter; Role of microorganisms in soil fertility. Soil health and quality: Microbial indicators

Unit 3: Bioremediation

Bioremediation of polluted soils; Biological control. Other topics of current interest.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Seminar presentation by students.
- Case studies

VIII. Learning outcome

With this course, the students are expected to be able to learn

- Latest trends in soil microbiology like diversity, biological control and bioremediation.

IX. Suggested Reading

Websites

- https://www.springer.com/in/book/9789811073793
- https://www.researchgate.net/publication/322952969_Advances_in_Soil_Microbiology_Recent_Trends_and_Future_Prospects_Volume_2_Soil-Microbe-Plant_Interaction
- Selected articles from journals.

I. Course Title : Recent Approaches in Environmental Microbiology

II. Course Code : MICRO 604

III. Credit Hours : 2+0

IV. Why this Course?

The activities of the microorganisms at large in nature/ environment are considered in this course. Microbes play far more important roles in nature than their small sizes would suggest. In order to evaluate the roles of microorganisms in ecosystems, it is essential to understand the precise natural habitats and how their activities can be explored.

V. Aim of the course

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

The course is organized as follows:

No.	Blocks	Units
1.	Recent environmental issue	1. Basic concepts and environmental issues

		2. Methodology of environmental management 3. Microbial waste treatment.
2.	Energy harnessing from organic waste	1. Pollution through conventional fuel 2. Renewable sources of energy.
3.	Treatment of waste for safe disposal	1. Disposal of domestic and industrial wastes 2. Global environmental problems

VI. Theory

Block 1: Recent Environmental Issue

Unit 1: Basic concept and environmental issues

Types of environmental pollution; problems arising from high-input agricultural residues. Air and water pollution.

Unit 2: Methodology of environmental management

Waste water treatment -physical, chemical, biological and microbial processes; need for water and natural resource.

Unit 3: Microbial waste treatment

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

Block 2: Energy Harnessing from Organic Waste

Unit 1: Pollution through conventional fuel

Conventional fuels and their environmental impact.

Unit 2: Renewable sources of energy.

Energy from solid waste; ; biogas; land filling, microbial hydrogen production; use of agro-industrial waste, agricultural waste for sugar to alcohol; gasohol; biodegradation of lignin and cellulose; biopesticides; biofertilizers; composting; vermiculture, etc.

Block 3: Treatment of Waste for Safe Disposal

Unit 1: Disposal of domestic and industrial wastes.

Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by micro-organisms.

Unit 2: Global environmental problems

Ozone depletion, UV-B, greenhouse effects, and acid rain; biodiversity and its conservation; Microbial and biotechnological approaches for the management of environmental problems.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Seminar presentation by students.
- Case studies

VIII. Learning outcome

With this course, the students are expected to be able to learn

- Latest trends in environmental microbiology like Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by micro-organisms
- Renewable and non-Renewable resources of energy; energy from solid waste; conventional fuels and their environmental impact; biogas; land filling, microbial hydrogen production

IX. Suggested Reading

- Evans GM and Furlong JC. 2002. *Environmental Biotechnology: Theory and Application*. Wiley International.
- Jordening HJ and Winter J. 2006. *Environmental Biotechnology: Concepts and Applications*. Wiley-VCH Verlag.

Websites

- https://www.springer.com/series/11961
- http://microbiology.ucsc.edu.
- http://www.asm.org

I. Course Title : Plant Microbe Interactions

II. Course Code : MICRO 605*

III. Credit Hours : 1+1

IV. Why this Course?

In the course, interactions between plants and microbes are discussed on general and detailed level for both pathogenic and symbiotic interactions. This course will be helpful in imparting knowledge to student about Infection mechanisms, defense of plants and stress responses and a large number of important problems within agriculture, horticulture and forestry

V. Aim of the course

The aim is to familiarize the students with the biochemical and biophysical mechanisms, genetics, genomics, proteomics and advanced microscopy, spectroscopy of different interfaces of beneficial and pathogenic plant microbe interactions. Molecular analysis of relevant factors in the plant and microbes, and components that modulate plant-microbe interactions for soil and plant health for sustaining crop productivity.

The course is organized as follows:

No.	Blocks	Units
1.	Types of eco system and microbial interaction	1. Different interfaces of interactions. 2. Ecosystem- Concept and Dynamics.
2.	Signaling and interaction among microbes	1. Microbial interaction.
3.	Genomic and proteomic study in plant microbe interaction.	1. Methodology/resources in plant-microbe interaction.

VI. Theory

Block 1: Types of Ecosystem and Microbial Interaction

Unit 1: Different interfaces of interactions

Plant-microbe, microbe-microbe, soil- microbe, soil-plant-microbe interactions leading to symbiotic (rhizobial and mycorrhizal, *Azolla-Anabaena*), associative, endophytic and pathogenic interactions.

Unit 2: Ecosystem- Concept and Dynamics

Types of ecosystems: Concept and dynamics of ecosystem, Food chain and energy flow, Microbial communities in the soil. Community dynamics and population interactions employing DGGE, TGGE, T-RFLP.

Block 2: Signaling and Interaction among Microbes

Unit 1: Microbial interaction

Quorum-sensing in bacteria, flow of signals in response to different carbon or other substrates and how signals are recognized.

Block 3: Genomic and Proteomic Study in Plant Microbe Interaction

Unit 1: Methodology/resources in plant-microbe interaction

Methodology/resources to study plant-microbe interaction, biosensors, transcriptome profiling, metabolic profiling, genomics, and proteomics Induced systemic resistance against pathogens and tolerance against abiotic stress: Molecular basis; Molecular diversity of microbes, plants and their interactions including transgenic microbes and plants.

VII. Practicals

- Phylochip based microbial community analyses-
- Endophytic and phyllosphere microbial community
- PCR-DGGE-Rhizosecretion secretome -FT-IR, HPLC
- Multifunctional protein identification and characterization using 2DE, MALDI-TOF.
- Examination of mycorrhizal infection in roots of different plants.
- Characterization of PGPR; Quantification of siderophores, HCN and IAA

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion

- o Case Analysis and case studies
- o Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to: Better understanding of soil – plant – microbe interaction and how the plant/ microbial system select their host. In addition this course will also provide new insight about the various biomolecules secreted by the plant root as well as microbes which forms the basis for their intimate association and exert multiple benefits to the plants.

X. Suggested Reading

- Kosuge T and Nester, E.W. 1989. *Plant Microbe Interactions: Molecular and Genetic Perspectives*, Vol.I-IV, McGraw Hill.
- Paul Eldor, A. 2007. *Soil Microbiology, Ecology and Biochemistry*
- Robert L. Tate III. 1995. *Soil Microbiology*, John Wiley & Sons, INC.
- Sylvia David, M., Fuhrmann, T.A., Hartel, P.G. and Zuberer, D.A. 2005. *Principles and Applications in Soil Microbiology* (II nd Edition).
- Verma, D.P.S. and Kohn, T.H. 1984. *Genes involved in Microbe-Plant Interactions,* Springer-Verlag
- Jaya Kumar Arjun, Kumarapillai Harikrishnan. 2011. Metagenomic analysis of bacterial diversity in the rice rhizosphere soil microbiome. *Biotechnol. Bioinf. Bioeng*. 1(3): 361-367
- Andrea Porras-Alfaro and Paul Bayman.2011. Hidden Fungi, Emergent Properties: Endophytes and Microbiomes. *Annu. Rev. Phytopathol*. 49: 291-315.
- Eleonora Rolli *et al*. 2014. Improved plant resistance to drought is promoted by the root associated microbiome as a water stress-dependent trait. *Environmental Microbiology*. doi: 10.1111/1462-2920.12439
- Roeland L. Berendsen, Corne´ M.J. Pieterse and Peter A.H.M. Bakker. 2012. The rhizosphere microbiome and plant health. *Trends in Plant Science*, Vol. 17, No. 8.
- Josep Penuelas and Jaume Terradas. 2014. The foliar microbiome. *Trends in Plant Science*. http://dx.doi.org/10.1016/j.tplants.2013.12.007

Journals

- Advances in Microbial Physiology
- Annual Review of Genetics/Biochemistry
- Annual Review of Microbiology
- Applied and Environmental Microbiology
- Biology and Fertility Soils
- Indian Journal of Microbiology
- Journal of Bacteriology
- Journal of Basic Microbiology
- Microbiology and Molecular Biology Reviews
- Nature/Science/EMBO Journal
- Reviews in Microbiology and Biotechnology
- Soil Biology and Biochemistry
- Trends in Biotechnology

- Trends in Microbiology
- Trends in Plant Sciences

Websites

- http://testweb.science.uu.nl/pmi/
- popups.ulg.ac.be/1780-4507/index.php?id=7578
- www.researchgate.net/...The_rhizosphere_microbiome_and_plant_health...
- journal.frontiersin.org/Journal/10.3389/fpls.2013.00165/abstract