UNIVERSITY OF HORTICULTURAL SCIENCES, BAGALKOT

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No. R/UHSB/ AC-35/ 1537 / 2022-23 Date: 20.03.2023

NOTIFICATION

Sub : Course and Syllabus for Master's and Doctoral degree programmes as per the recommendations of the BSMA Committee from the academic year 2022-23 reg.

Ref :
1. This office notification No.R/UHSB/Ac-34/Eligibility Criteria /285 /2022-23 dtd:18.06.2022
2. Corrigendum No. R/UHSB/AC-34/BSMA/430/2022-23, dt.20.07.2022
3. Minutes on Item No: 03 of 35th Academic Council meeting held on 10.01.2023
4. This office e-mail dtd 27.02.2023 and 09.03.2023
5. E-mail received from the Dean(PGS), UHS, Bagalkot dtd:17.03.2023
6. Recommendation of the Dean (PGS), UHS, Bagalkot
7. Approval of the Director of Education, UHS, Bagalkot
8. Orders of the Hon'ble Vice Chancellor, UHS, Bagalkot

In pursuance of the above references, the Department names, Course names, Symbols, credit hours, course structure for Master's and Doctoral degree programmes are notified as per the above notification/Corrigendum (Ref 1 & 2). Further, as per the recommendations of the BSMA Committee and decision of the Academic Council (Ref 3) the **"Course and Syllabus for Master's and Doctoral degree programmes 2022-23"** are hereby notified as enclosed in Annexure I & II respectively. These Course and Syllabus are applicable from the academic year 2022-23 and onwards.

By Order,

REGISTRAR

REGISTRAR
UHS, BAGALKOT.

Enclosure: Annexure I & II

To: 1. All the members of the Academic Council
2. All the Deans of UHS, Bagalkot
3. The Director, SC/ST cell, UHS, Bagalkot
4. The Controller of Examination, CEEU, UHS, Bagalkot
5. All Academic Units/ Account Sections of UHS, Bagalkot

6. The Personal Secretary to the Hon'ble Vice-Chancellor, UHS, Bagalkot
7. Notice Board- Concerned Colleges, UHS, Bagalkot

Copy to: The University Librarian, UHS, Bagalkot with a request to upload the same in the University website

Copy submitted for kind information to: The Director of Education, UHS, Bagalkot

UNIVERSITY OF HORTICULTURAL SCIENCES BAGALKOT

COURSE SYLLABUS

FOR

DOCTORAL DEGREE PROGRAMMES

(Revised Syllabus as per BSMA)

SEMESTER SYSTEM

2022-23

OFFICE THE DEAN POSTGRADUATE STUDIES

UNIVERSITY OF HORTICULTURAL SCIENCES BAGALKOT - 587 104

UNIVERSITY OF HORTICULTURAL SCIENCES BAGALKOT

Doctoral Degree Programmes

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COURSE CONTENTS

FRUIT SCIENCE

Sl.No.	Course No.	Course Title	Credit Hours
Major courses (Minimum 12 credits)			
1	FSC 601*	Innovative Approaches in Fruit Breeding	3+0
2	FSC 602*	Modern Trends in Fruit Production	3+0
3	FSC 603	Recent Developments in Growth Regulation	3+0
4	FSC 604	Advanced Laboratory Techniques	1+2
5	FSC 605	Arid and Dry Land Fruit Production	2+0
6	FSC 606	Abiotic Stress Management in Fruit Crops	2+1
7	FSC 607	Biodiversity and Conservation of Fruit Crops	2+1
8	FSC 608	Smart Fruit Production	2+0
9	FSC 609	Application of Biotechnological Tools in Fruits Crops	2+1
10	FSC 610	Management of Abiotic Stress in Fruit Crops	2+1
11	FSC 611	Genomics and Bioinformatics in Fruit Crops	2+0
12	FSC 612	National and International Current Issues in Fruits Production	3+0
13	FSC 613	Organic Production of Fruit Crops	1+1
14	FSC 614	Advances in Canopy Management in Fruit Crops	1+1
15	FSC 615	Advances in Banana Culture	1+1
16	FSC 616	Advances in Mango and Citrus Culture	1+1
17	FSC 617	Advances in Viticulture	1+1
18	FSC 671	Qualifying Examination	0+4
19	FSC 681	Seminar-I	0+1
20	FSC 682	Seminar-II	0+1
21	FSC 683	Seminar-III	0+1
22	FSC 691	Research	0+70

*** Compulsory among major courses**

FSC 601	Innovative Approaches in Fruit Breeding	3+0

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 hybridization (alien genes). omiXisgene introgression and wide

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, kiwifruit, plums, peaches, apricot, cherries, nectarines, nut crops, Pineapple, Annona, sapota

Suggested Referances

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.

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.

FSC 602	Modern Trends in Fruit Production	3+0

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, Walnut, Pecan, Strawberry, Kiwifruit., Aonla, jackfruit.

Suggested Referances

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.

FSC 603	Recent Developments in Growth Regulation	3+0

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.

Suggested Referances

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.

FSC 604	Advanced Laboratory Techniques	1+2

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.

Practicals

- 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

Suggested Referances

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.

FSC 605	Arid and Dryland Fruit Production	2+0

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.

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, woodapple, bael, jamun, date palm, Dragon fruit, cactus pear, khejri, kair, pilu, lasoda, manila tamarind, tamarind, monkey jack, mahua, khirni, amra, seabuckthorn, chilgoza, cafel, rhododendron, box myrtle, chironji, phalsa, karonda, Fig, paniala and other minor fruits of regional importance

Suggested Referances

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).

FSC 606	Abiotic Stress Management in Fruit Crops	2+1

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.

Practicals

- 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);
- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

Suggested Referances

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.

FSC 607	Biodiversity and Conservation of Fruit Crops	2+1

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.

Practicals

- 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).
- Crops: Mango, citrus, guava, banana, papaya, grapes, custard, apple, ber, aonla, malus sp., Prunus sp. and litchi.

Suggested Referances

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.

FSC 608	Smart Fruit Production	2+0

Theory

Block 1: Introduction

Unit I: Importance and Overview: Introduction and importance; concepts andapplications 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-techfacilities.

Suggested Referances

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 Departmen

FSC 609	Application of Biotechnological Tools in Fruits Crops	2+1

Theory

Basic principles of plant tissue-culture; morphogenetic potential of higher plants and regeneration pathways. Application of plant tissue culture techniques in crop improvement with emphasis on fruit crops, single cell and suspension culture, in vitro mutagenesis, somaclonal variation, embryo culture and rescue, anther culture and haploid production. Protoplast isolation, fusion and organogenesis, Agrobacterium-mediated genetic transformation and cryobiology. In vitro germplasm conservation, genetic diversity analysis using DNA markers.

Practicals

General acquaintance with a tissue culture laboratory; Methods of aseptic culture and sterilization procedure; Stock solutions and preparation of culture media; In vitro culture establishment and plant regeneration, Embryo culture and embryo rescue;

Anther isolation and culture; In vitro mutagenesis using EMS and gamma irradiation; In vitro screening for sodium tolerance; Agrobacterium- mediated genetic transformation of tobacco; DNA isolation and molecular markers analysis of plants; Techniques of low temperature germplasm storage, cryo- preservation and visit to NBPGR cryo- bank.

Suggested Referances

Balasubramanian, D., Bryce, C.F.A., Dharmalingam, K., Green, J. and Jayamaran, K. 1998. London

Bojwani, S.S. and Razdan, M.K. 1983. Plant Tissue Culture: Theory and Practices, Elsevier, Amsterdam.

Chadha, K.L., Ravindran, P.N. and Sahijaram, Leela 2000. Bio-technology in Horticulture and Plantation Crops. Malhotra Publishing House, New Delhi. Concepts in Biotechnology. University Press, India. Hyderabad

Gupta, P.K. 1999. Elements of Biotechnology, Rastogi publications, Meerut, India.

Hammerscchlag Z.A. and Litz, R.E. 1997. Biotechnology of Fruit and Nut Crops, CABI, U.K.

Primrose, S.B. 1987. Modern Biotechnology. Blackwell Scientific Co., USA. Razdan, M.K. 1993. An Introduction to Plant Tissue Culture. Oxford & IBH, Publishing Co. Pvt. Ltd., New Delhi.

Singh, B.D. 1999. Biotechnology, Kalyani Publishers, Ludhiana.

Street, H.E. 1973. Plant Tissue and Cell Culture. Blackwell Publications, London.

Vasil, I.K. 1967. Cell Culture and Somatic Cell Genetics. Academic Press, London.

FSC 610	Management of Abiotic Stress in Fruit Crops	2+1

Theory

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 CO2, industrial wastes, impact of stress in horticultural crop production, stress indices, physiological and biochemical factors associated with stress, horticultural crops suitable for different stress situations. Crop modeling for stress situations, cropping system, assessing the stress through remote sensing, understanding adaptive features of crops for survival under stress,

interaction among different stress and their impact on crop growth and productivity. Greenhouse effect and methane emission and its relevanceto 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, cropping systems, stability and sustainability indices.

Practicals

Seed treatment / hardening practices, container seedling production, analysis of soil moisture estimates (FC, ASM, PWP), analysis of plant stress factors, RWC, chlorophyll flurosence, chlorophyll stability index, ABA content, plant waxes, stomatal diffusive resistance, transpiration, photosynthetic rate etc. under varied stress situations, influence of stress on growth and development of seedlings and roots, biological efficiencies, WUE, solar energy conversion and efficiency, crop growth sustainability indices, economics of stress management, visit to orchards and water shed locations.

Suggested References

Bhumm A, 1988 Plant Breeding for Stress Environment. CRC. USA

Christiansen MN & Lewis CF, 1982 Breeding plant for Less Favourable Environments. Wiley Inter. Science. New York

Gupta US, 1990 Physiological Aspects of Dry Farming. Madison

Kramer PJ, 1980 Drought Stress and the Origin of Adaptation. In: Adaptation of Plant to Water and High Temperature Stress. John Wiley & Sons. New York Levitt J, 1972 Response of Plant to Environment Stresses. Academic Press. New York

Maloo SR. 2003. Abiotic Stress and Crop Productivity. Agrotech Publ. Academy. Udaipur India

Mussell H & Staples R. 1979. Stress Physiology in Crop Plants. Wiley Inter. Science. New York

Nickell LG. 1983. Plant Growth Regulating Chemicals. CRC. Boca Ration, Florida Peter KV. (Ed.). 2008. Basics of Horticulture. New India Publ. Agency.New Delhi Turener NC & Kramer PJ. 1980. Adaptation of Plants to Water and High Temperature Stress. John Wiley & Sons. New York.

FSC 611	Genomics and Bioinformatics in Fruit Crops	2+0

Theory

Introduction to bioinformatics and computational genomics, database fundamentals-biological databases, horticultural genome and protein databases, functional genomics. Dynamic Programming Sequence Alignment, BLAST search engine, FASTA search engine, Microarrays- Microarray Clustering and Classification, Terminologies and Ontologies-EcoCYC knowledge base of E. coli metabolism-Description of UMLS Semantic Network. Multiple Sequence Alignment, MSA algorithm descriptions, ClustalW, 1D Motifs, Algorithms and Databases, methods for sequence weighting, BLOCKS database, Making BLOCK motifs, PROSITE database, 3D structure alignment, SCOP, DALI, LOCK, MUSTA algorithm for geometric hashing and multiple alignment. Phylogenetic algorithms-Treebase database of phylogenetic information for plants mostly, Tree of Life Page, Samples from the Tree of Life, Ribosomal Database Project, Natural Language Processing, Proteomics, 3D Motifs, Applications and Integration with Horticulture, Final Thoughts.

Suggested References

Attwood TK & Parry Smith DJ, 2006. Introduction to Bioinformatics Pearson Edu. Baxevanis AD., 2005 Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins 3rd Ed. Wiley.Bourne PE & Weissig H. (Eds.), 2004. Structural Bioinformatics. John Wiley & Sons. New York

Durbin R, Eddy SR, Krogh A & Mitchison G, 1999. Biological Sequence Analysis: Probabilistic Model of Proteins and Nucleic Acids. Cam UK

FSC 612	National and International Current Issues in Fruits Production	3+0

Theory

National and international scenario in fruit production and trade. Climate change and fruit production. Abiotic and biotic factors influencing production, productivity and fruit quality. Senile and seedling orchards- Replant problems and top working, in-situ rain water harvesting and enhancing water use efficiency, Nutrient and irrigation scheduling, Fruit crop based cropping systems, pesticidal residues and MRLs issues in fresh produce. GAPs in fruit production, HiTech banana & citrus production, Quality grape production in sub- tropical regions, crop regulation in pomegranate and guava, Quality plant material. Complex problems confronting fruit cultivation and their management: Alternate bearing in mango & apple, mango malformation, panama wilt of banana, citrus decline, guava wilt, coconut wilt, apple scab, chilling and pollination problems in temperate fruits, frost and virus problems in papaya and bacterial oil spot in pomegranate.

Suggested Referances

Blumm, A. 1988. Plant Breeding for Stress Environments. CRC Press, USA.

Bose, T.K., Mitra S.K., Farooqi A.A. and Sadhu, M.K. 1999. Tropical Horticulture. Vol. I. Naya Prokash, Kolkata.

Bose, T.K., Mitra, S.K. and Sanyal, D. (Ed.). 2002. Fruits of India – Tropical and Sub-tropical. 3rd Ed. Vols. I, II. Naya Udyog, Kolkata.

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Chadha, K.L. and Rethinam, P. (Eds.). 1993. Advances in Horticulture. Vol. IX. Plantation Crops and Spices. Part-I. Malhotra Publ. House, New Delhi.

Christiansen, M.N. and Lewis, C.F. 1982. Breeding Plants for Less Favourable Environments. Wiley Inter. Science, USA.

Hsiao, T.C. 1973. Plant Responses to Water Stress. Ann. Rev. Plant Physiology 24: 519-570. University of California Davis

Levitt, J. 1972. Response of Plants to Environmental Stresses. Academic Press, USA.

Nakasone, H.Y. and Paull, R.E. 1998. Tropical Fruits. CABI, UK.

Turener, N.C. and Kramer, P.J. 1980. Adaptation of Plants to Water and High Temperature Stress. John Wiley & Sons. New York

FSC 613	Organic Production of Fruit Crops	1+1

Theory

Organic horticulture – definition, synonyms and misnomers, principles, methods, merits and demerits. Organic farming systems, components of organic horticultural systems, different organic inputs, their role in organic horticulture, role of

biofertilizers, biodynamics and the recent developments. EM technology and its impact in organic horticulture, indigenous practices of organic farming, sustainable soil fertility management, weed management practices in organic farming, biological/ natural control of pests and diseases, organic horticulture in quality improvement. GAP - Principles and management, HACCP exercise, certification of organic products and systems, agencies involved at national and international levels, standards evolved by different agencies. Constraints in certification, organic horticulture and export, IFOAM and global scenario of organic movement, post-harvest management of organic produce.

Practicals

Features of organic orchards, working out conversion plan, Input analysismanures, nutrient status assessment of manures, biocomposting, biofertilizers and their application, panchagavya preparation and other organic nutrients application, methods of preparation of compost, vermicompost, green manuring, preparation of neem products and application, BD preparations and their role, EM technology and products, biological/natural control of pests and diseases, soil solarization, frame work for GAP, case studies, HACCP analysis, residue analysis in organicproducts, documentation for certification, visit to fields cultivated under organic practices

Suggested Referances

Claude A, Vandana S, Sultan I, Vijaya L, Korah M & Bernard D. 2000. The Organic Farming Reader. Other Indian Press, Goa.

Gaur AC, Neblakantan S & Dargan KS. 1984 Organic Manures. ICAR. New Delhi

Lampkin N & Ipswich. 1990. Organic Farming. Farming Press. London.

Lampkin NH & Padel S. 1992. The Economics of Organic Farming – An International Perspective. CABI. UK

Palaniappan and Annadurai. 2008. Organic Farming- Theory and Practise. Scientific Publ. Jodhpur, India

Peter KV. 2008. (Ed.). Basics of Horticulture. New India Publ. Agency. New Delhi.

Rao S. 1977. Soil Microorganism and Plant Growth. Oxford & IBH. New Delhi

FSC 614	Advances in Canopy Management in Fruit Crops	1+1

Theory

Canopy management - importance and advantages; factors affecting canopy development. Canopy types and structures with special emphasis on geometry of planting, canopy anipulation for optimum utilization of light. Light interception and distribution in different types of tree canopies. Spacing and utilization of land area - Canopy classification; Canopy management through rootstock and scion. Canopy management through plant growth inhibitors, training and pruning and management practices. Canopy development and management in relation to growth, flowering, fruiting and fruit quality in temperate fruits, grapes, passion fruits, mango,sapota, guava, citrus and ber.

Practicals

Study of different types of canopies, training of plants for different canopy types, canopy development through pruning, use of plant growth inhibitors, geometry of planting; study on effect of different canopy types on production and quality of fruits.

Suggested Referances

Chadha KL & Shikhamany SD. 1999. The Grape, Improvement, Production and Post Harvest Management. Malhotra Publ. House. Delhi

Pradeepkumar T, Suma B, Jyothibhaskar & Satheesan KN. 2008. Management of Horticultural Crops. New India Publ. Agency. New Delhi

FSC 615	Advances in Banana Culture	1+1

Theory

Recent area, production, marketing and export. Recent advances in production technology and culture of Banana. Approaches for organic production of banana. Production problems and management approaches. Important case studies in banana. Problems and prospects of crop improvement in banana.

Practicals

Identification of varieties/clones. Propagation methods. Study of vegetative growth, flowering and fruiting. Study of special horticultural practices. Criteria for harvesting and ripening. Important pests, diseases and their management. Orchard efficiency analysis. Visit to progressive orchards and research centre.

Suggested References

Robinson, J.C., 1996, Bananas and Plantians, CAB UK

Kanchan, K, and Srivatsava, 2009, Systemic description of fruit crops, International Book Distributing co. Lucknow

Chadha, K.L. and O.P. Pareek, (Eds). 1993. Advances in Horticulture. Vol. III. Fruit Crops. Malhotra Publishing House, New Delhi.

FSC 616	Advances in Mango and Citrus Culture	1+1

Theory

Recent area, production, marketing and export. Recent advances in production technology and culture of Citrus. Approaches for organic production of citrus. Production problems and management approaches. Important case studies in citrus. Problems and prospects of crop improvement in citrus.

Practicals

Identification of varieties/clones. Propagation methods. Study of vegetative growth, flowering and fruiting. Criteria for harvesting and ripening. Important pests, diseases and their management. nutritional disorders and their management strategies, Orchard efficiency analysis. Visit to progressive orchards and research centre.

Suggested References

Shaym Singh, 2001, Citrus, International Book Distributing Co. Lucknow

Ting, S.V., Russell, L., 1986, Citrus Fruits and their Products, Marcel Dekker Inc. New York

Kanchan, K, and Srivatsava, 2009, Systemic description of fruit crops, International Book Distributing co.Lucknow

Chadha, K.L. and O.P. Pareek, (Ed). 1993. Advances in Horticulture. Vol. III. Fruit Crops. Malhotra Publishing House, New Delhi

FSC 617	Advances in Viticulture	1+1

Theory

Recent area, production, marketing and export. Recent advances in production technology and culture of grape including wine grape. Approaches for organic production of grape. Production problems and management approaches. Important case studies in grape. Problems and prospects of crop improvement in grape.

Practicals

Identification of varieties/clones. Propagation methods. methods of training and pruning, bud analysis, Study of vegetative growth, flowering and fruiting. Criteria for harvesting and ripening. Important pests, diseases and their management. Phsiological disorders and their management. Vineyard efficiency analysis. Visit to progressive vineyard and research centre.

Suggested References

Shanmugavelu, 2003. Grape Cultivation and Processing, Agrobios (India) Jodhpur

Kanchan, K, Srivatsava, 2009, Systemic description of fruit crops, International Book Distributing co. Lucknow

Chadha, K.L. and O.P. Pareek, (Ed). 1993. Advances in Horticulture. Vol. III. Fruit Crops. Malhotra Publishing House, New Delhi

VEGETABLE SCIENCE

Sl. No.	Course No.	Course Title	Credit Hours
Major courses (Minimum 12 credits)			
1	VSC 601*	Recent Trends in Vegetable Production	3+0
2	VSC 602*	Advances in Breeding of Vegetable Crops	3+0
3	VSC 603	Abiotic Stress Management in Vegetable Crops	2+1
4	VSC 604	Seed Certification, Processing and Storage of Vegetable Seeds	2+1
5	VSC 605	Breeding for Special Traits in Vegetable Crops	2+0
6	VSC 606	Biodiversity and Conservation of Vegetable Crops	2+1
7	VSC 607	Biotechnological Approaches in Vegetable Crops	2+1
8	VSC 608	Advanced Laboratory Techniques for Vegetable Crops	1+2
9	VSC 609	Advances in Solanaceous Vegetables	1+1
10	VSC 610	Advances in Cucurbitaceous Vegetables	1+1
11	VSC 611	Advances in Cole Crops	1+1
12	VSC 612	Advances in Bulbous and Root Vegetables	1+1
13	VSC 613	Export Oriented Vegetables	1+1
14	VSC 614	Improvement and Production Technology of Perennial and Under Exploited Vegetables	2+1
15	VSC 615	Improvement and Production Technology of Exotic Vegetables	1+1
16	VSC 616	Biometrical Genetics	1+1
17	VSC 671	Qualifying Examination	0+4
18	VSC 681	Seminar-I	0+1
19	VSC 682	Seminar-II	0+1
20	VSC 683	Seminar-III	0+1
21	VSC 691	Research	0+70

*** Compulsory among major courses**

VSC 601	Recent Trends in Vegetable Production	3+0

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 bioferilizers; 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; net house production; cropmodeling, organic gardening; vegetable production for export and 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, 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.

Suggested Referances

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. 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.

Rubatzky VE and Yamaguchi M. (Eds.). 1997. World vegetables: principles, production and nutritive values. Chapman and Hall.

Saini GS. 2001. *A Text Book of oleri and flori culture*. Aman Publishing House.
Salunkhe DK and Kadam SS. (Ed.). 1998. *Hand book of vegetable science and technology: production, composition, storage and processing*. Marcel Dekker.
Shanmugavelu KG. 1989. *Production technology of vegetable crops.* Oxford and IBH. 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.

VSC 602	Advances in Breeding of Vegetable Crops	3+0

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*—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

Suggested Referances

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, 459p

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.

Prohens Jand Nuez F.2008, Vegetables I, Springer, USA.

ProhensJandNuezF.2008, Vegetables II, Springer, USA.

Rai N and Rai M. 2006. *Heterosis breeding in vegetable crops*. New India Publ. Agency.

Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi. Simmonds NW. 1978. *Principles of crop improvement*. Longman.

Ravindra Mulge, 2021, Vegetable Crops Breeding, NIPA, New Delhi and CRC Press, Taylor & Francis Group London, New York.

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.

VSC 603	Abiotic Stress Management in Vegetable Crops	2+1

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 chemicals and antitranspirants in alleviation of different stresses.

Practicals

- 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.

Suggested Referances

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.

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Rao NK. (Eds.). 2016. Abiotic stress physiology of horticultural crops. Springer publication.

VSC 604	Seed Certification, Processing and Storage of Vegetable Seeds	3+0

Theory

Unit I : Seed certification, history, concepts and objectives, seed certification agency, phases of seed certification, Indian Minimum seed Certification standards, Planning and management of seed certification programmes.

Unit II : Principles and procedures of field inspection, seed sampling, testing and granting certification, OECD certification Schemes.

Unit III : Principles of seed processing, Methods of seed drying and cleaning, seed processing plant- Layout and design, seed treatment, seed quality enhancement, packagingand marketing.

Unit IV : Principles of Seed Storage, orthodox/ recalcitrant seeds, types of storage (open, bulk, controlled, germplasm, cryopreservation), factors affecting seed longevity in storage (Pre and post harvest factors).

Unit V : Seed aging and deterioration, maintenance of seed viability and vigor during storage,storage methods, storage structures, transportation and marketing of seeds.

Practicals

- 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.

Suggested Referances

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.

VSC 605	Breeding for Special Traits in Vegetable Crops	2+0

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.

Suggested Referances

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.

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Paroda RS and Kalloo G. (Eds.). 1995. *Vegetable research with special reference to hybrid technology in Asia-Pacific Region*. FAO.

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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. Rout GR and Peter KV. 2008. *Genetic engineering of horticultural crops.* Academic press, Elsevier, USA

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.

VSC 606	**Biodiversity and Conservation of Vegetable Crops**	2+1

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.

Practicals

- 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.

Suggested Referances

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.

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Jackson M, Ford-Lloyd B and Parry M. 2014, *Plant genetic resources and climate change*. CABI, Wallingford, UK

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VSC 607	**Biotechnological Approaches in Vegetable Crops**	**2+1**

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

Practicals

- 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).

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Vasil TK, Vasi M, While DNR and Bery HR. 1979. *Somatic hybridization and genetic manipulation in plants, plant regulation and world agriculture*. Planum Press.

VSC 608	Advanced Laboratory Techniques for Vegetable Crops	1+2

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.

Practicals

- 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.).

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VSC 609	Advances in Solanaceous Vegetables	1+1

Theory

Present status and prospects of solanaceous vegetables cultivation; nutritional and medicinal values; climate and soil as critical factors in vegetable production; choice of varieties; 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; containerized culture for year round vegetable production; low cost polyhouse; net house production; crop modeling, organic gardening; vegetable production for pigments, evolution, distribution, cytogenetics, genetic resources, genetic divergence, types of pollination and fertilization mechanisms, sterility and incompatibility, anthesis and pollination, hybridization, inter-varietal, interspecific and inter-generic hybridization, heterosis breeding, inheritance pattern of traits, qualitative and quantitative, plant type concept and selection indices, genetics of spontaneous and induced mutations, problems and achievements of mutation breeding, ploidy breeding and its achievements, in vitro breedings; breeding techiques for improving quality and processing characters; breeding for stresses, mechanism and genetics of resistance, breeding for salt, drought; low and high temperature; toxicity and water logging resistance, breeding for pest, disease, nematode and multiple resistance, export and processing, of:

UNIT I: Potato

UNIT II: Tomato

UNIT III: Brinjal

UNIT IV: Chilli and capsicum

Practicals

Nursery techniques; practices in indeterminate and determinate vegetable growing and organic gardening; portrays and ball culture; diagnosis of nutritional and physiological disorders; analysis of physiological factors like anatomy; photosynthesis; light intensity in different cropping situation; assessing nutrient status, use of plant growth regulators; practices in herbicide application; estimating water requirements in relation to crop growth stages, maturity indices; production constraints; analysis of different cropping system in various situation like cold and hot set; vegetable waste recycling management; quality analysis; marketing survey of the above crops; Designing of breeding experiments, screening techniques for abiotic stresses, screening and rating for pest, disease and nematode resistance, estimation of quality and processing characters, screening for-quality improvement, estimation of heterosis and combining ability, induction and identification of mutants and polyploids, distant hybridization and embryo rescue techniques.

Suggested Referances

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Dhillon, B. S., Saxena, S. Agrawal, A. and Tyagi, R. K. 2005, Plant Genetic Resources: Horticulture crops . Narosa publishing House. New Delhi, India.

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development. Research Periodical and Book Publishing House; .p. 104- 113.

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VSC 610	**Advances in Cucurbitaceous Vegetables**	**1+1**

Theory

Present status and prospects of cucurbitacious vegetable cultivation; nutritional and medicinal values; climate and soil as critical factors in vegetable production; choice of varieties; 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; low cost polyhouse; net house production; crop modeling, organic gardening; vegetable production for pigments, evolution, distribution, cytogenetics, genetic resources, genetic divergence, types of pollination and fertilization mechanisms, sterility and anthesis and pollination, hybridization, inter-varietal, interspecific and inter-generic hybridization, heterosis breeding, inheritance pattern of traits, qualitative and quantitative, plant type concept and selection indices, genetics of spontaneous and induced mutations, problems and achievements of mutation breeding, ploidy breeding and its achievements, in vitro breeding; breeding techniques for improving quality and processing characters; breeding for stresses, mechanism and genetics of resistance, breeding for salt, drought; low and high temperature; toxicity and water logging resistance, breeding for pest, disease, nematode and multiple resistance, export and processing, of:

UNIT I : Cucumber

UNIT II : Water melon

UNIT III : Musk melon

UNIT IV : Gourds

UNIT V : Squashes and pumpkins

Practicals

Practices in cucurbitacious vegetable growing and organic gardening;; diagnosis of nutritional and physiological disorders; analysis of physiological factors like anatomy; photosynthesis; light intensity in different cropping situation; assessing nutrient status, use of plant growth regulators; practices in herbicide application; estimating water requirements in relation to crop growth stages, maturity indices; production constraints; analysis of different cropping system in various situation like cold and hot set; vegetable waste recycling management; quality analysis ;marketing survey of the above crops; visit to vegetable and fruit malls and packing houses. Designing of breeding experiments, screening techniques for abiotic stresses, screening and rating for pest, disease and nematode resistance, estimation of quality and processing characters, screening for-quality improvement, estimation of heterosis and combining ability, induction and identification of mutants and polyploids, distant hybridization and embryo rescue techniques.

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Dhillon, B. S., Saxena, S. Agrawal, A. and Tyagi, R. K. 2005, Plant Genetic Resources: Horticulture crops . Narosa publishing House. New Delhi ,India

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Singh PK, Dasgupta SK and Tripathi SK. 2004. Hybrid Vegetable Development. International Book Distributing Co. Lucknow.

VSC 611	**Advances in Cole Crops**	**1+1**

Theory

Present status and prospects of vegetable cultivation; nutritional and medicinal values; climate and soil as critical factors in vegetable production; choice of varieties; 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; containerized culture for year

round vegetable production; low cost polyhouse; net house production; crop modeling, organic gardening; vegetable production for pigments, evolution, distribution, cytogenetics, genetic resources, genetic divergence, types of pollination and fertilization mechanisms, sterility and incompatibility, anthesis and pollination, hybridization, inter-varietal, interspecific and inter-generic hybridization, heterosis breeding, inheritance pattern of traits, qualitative and quantitative, plant type concept and selection indices, genetics of spontaneous and induced mutations, problems and achievements of mutation breeding, ploidy breeding and its achievements, in vitro breeding; breeding techniques for improving quality and processing characters; breeding for stresses, mechanism and genetics of resistance, breeding for salt, drought; low and high temperature; toxicity and water logging resistance, breeding for pest, disease, nematode and multiple resistance, export and processing, of

UNIT I : Cabbage

UNIT II :Cauliflower

UNIT III :Knol khol

UNIT IV : Sprouting broccoli and other cole crops

Practicals

Nursery techniques; practices in vegetable growing and organic gardening; portrays; diagnosis of nutritional and physiological disorders; analysis of physiological factors like anatomy; photosynthesis; light intensity in different cropping situation; assessing nutrient status, use of plant growth regulators; practices in herbicide application; estimating water requirements in relation to crop growth stages, maturity indices; production constraints; analysis of different cropping system in various situation like cold and hot set; vegetable waste recycling management; quality analysis; marketing survey of the above crops; visit to vegetable and fruit malls and packing houses. Designing of breeding experiments, Self incompatibility assay, screening techniques for abiotic stresses, screening and rating for pest, disease and nematode resistance, estimation of quality and processing characters, screening for-quality improvement, estimation of heterosis and combining ability, induction and identification of mutants, distant hybridization and embryo rescue techniques.

Suggested Referances

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Singh NP, Bharadwaj AK, Kumar A and Singh KM. 2004. Modern

Technology on Vegetable Production. International Book Distributing Co. Lucknow.

Singh PK, Dasgupta SK and Tripathi SK. 2004. Hybrid Vegetable Development. International Book Distributing Co. Lucknow.

VSC 612	**Advances in Bulbous and Root Vegetables**	**1+1**

Theory

Present status and prospects of bulbous and root vegetable crops cultivation; nutritional and medicinal values; climate and soil as critical factors in vegetable production; choice of varieties; 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; containerized culture for year round vegetable production; low cost polyhouse; net house production; crop modeling, organic gardening; vegetable production for pigments, evolution, distribution, cytogenetics, genetic resources, genetic divergence, types of pollination and fertilization mechanisms, sterility and incompatibility, anthesis and pollination, hybridization, inter-varietal, interspecific and inter-generic hybridization, heterosis breeding, inheritance pattern of traits, qualitative and quantitative, plant type concept and selection indices, genetics of spontaneous and induced mutations, problems and achievements of mutation breeding, ploidy breeding and its achievements, in vitro breeding; breeding techniques for improving quality and processing characters; breeding for stresses, mechanism and genetics of resistance, breeding for salt, drought; low and high temperature; toxicity and water logging resistance, breeding for pest, disease, nematode and multiple resistance, export and processing, of:

UNIT I : Onion

UNIT II : Garlic and other bulbous vegetable crops

UNIT III : Carrot

UNIT IV : Radish, turnip and beet root

Practicals

Nursery techniques; practices in bulbous and root vegetable crops growing and organic gardening; diagnosis of nutritional and physiological disorders; analysis of physiological factors like anatomy; photosynthesis; light intensity in different cropping situation; assessing nutrient status, use of plant growth regulators; practices in herbicide application; estimating water requirements in relation to crop growth stages, maturity indices; production constraints; analysis of different cropping system in various situation like cold and hot set; vegetable waste recycling management; quality analysis ;marketing survey of the above crops; visit to vegetable and fruit malls and packing houses. Designing of breeding experiments, identification of male sterile plants and assay, screening techniques for abiotic stresses, screening and rating for

pest, disease and nematode resistance, estimation of quality and processing characters, screening for-quality improvement, estimation of heterosis and combining ability, induction and identification of mutants and polyploids, distant hybridization and embryo rescue techniques.

Suggested Referances

Bose TK, Kabir J, Maity TK, Parthasarathy VA and Som MG. 2003. Vegetable Crops. Vols. I-III. Naya Udyog. Kolkata.

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VSC 613	**Export Oriented Vegetables**	**1+1**

Theory

UNIT I: India's position and potentiality in world trade; export promotion zones in India

UNIT II : Scope, produce specifications, quality and safety standards for export of vegetables viz., onion, chilli, okra, bittergourd, gherkin, etc

UNIT-III : Processed and value added products, post harvest managementfor export including packaging and cool chain; HACCP, codex ailmentarious, ISO certification; WTO 5.54 and it's implications, sanitary and photo sanitary measures

UNIT-IV : Seed and planting materials, Hi-tech nurseries, implications of PVP.

Practicals

Export promotion zones for vegetables and export of fresh vegetables and their products; quality standards of vegetables for export purpose; practical on quality standards for export, Quality standards of planting materials and seeds; Hi-tech nursery in vegetable crops, Sanitory and photo sanitary measures during export of vegetables;Post harvest management chain of vegetable produce for export.

Suggested Referances

V. K. Gondalia Rachana Bansal K. S. Jadav A. S. Shaikh, 2017, Export of Fruits and Vegetables from India: Growth, Opportunities and Challenges, Anand Agricultural University Anand- 388 110 (Gujarat)

M. Dahatreyulu, 1997, Export Potential of Fruits, Vegetables and Flowers From India, National Bank for Agriculture and Rural Development, Mumbai.

Agricultural and Processed Food Products Export Development Authority, http://apeda.gov.in

Directorate General of Foreign Trade, http://dgft.gov.in

E-Com Portal of Central Board of Excise and Custom, www.icegate.gov.in

Export Credit Guarantee Corporation of Inida Ltd. (ECGC Ltd.), www.ecgc.in

International Trade Centre, www.trademap.org

National Horticulture Board, http://nhb.gov.in

VSC 614	**Improvement and Production Technology of Perennial and Under Exploited Vegetables**	**2+1**

Theory

Present status and prospects of perennial and under exploited vegetable crops cultivation; nutritional and medicinal values; climate and soil, choice of varieties; nursery management; modern concepts in water and weed management; physiological basis of growth, yield and quality as influenced by chemicals and growth regulators; nutritional deficiencies, disorders and correction methods; different cropping systems; mulching; evolution, distribution, cytogenetics, genetic resources, genetic divergence, types of pollination and fertilization mechanisms, sterility and incompatibility, anthesis and pollination, hybridization, inheritance pattern of traits, selection indices, breeding techniques for improving quantity, quality and processing characters; breeding for stresses, mechanism and genetics of resistance, breeding for salt, drought; low and high temperature; toxicity and water logging resistance, breeding for pest, disease, nematode and multiple resistance, export and processing, of

UNIT I: Drumstick, Curry leaf, Cassava, yams, Asparagus and leek

UNIT II: Brussels's sprout, Chinese cabbage, broccoli, kale and artichoke.

UNIT III: Amaranth, celery, parsley, parsnip, lettuce, rhubarb, spinach, basella, bathu (chenopods) and chekurmanis.

UNIT IV: Elephant food yam, lima bean, winged bean, vegetable pigeon pea, jack bean and sword bean.

UNIT V: Sweet gourd, spine gourd, pointed gourd, Oriental pickling melon, snake gourd, Chow chow, and little gourd (kundru).

Practicals

Nursery techniques and practices in perennial and under exploited vegetables crops growing and organic gardening; diagnosis of nutritional and physiological disorders; analysis of physiological factors like anatomy; photosynthesis; light intensity in different cropping situation; assessing nutrient status, use of plant growth regulators; practices in herbicide application; estimating water requirements in relation to crop growth stages, maturity indices; production constraints; analysis of different cropping system in various situation like cold and hot set; vegetable waste recycling management; quality analysis ;marketing survey of the above crops; genetic variability, cytogenetic and genetic studies, Screening techniques for abiotic stresses, screening and rating for pest, disease and nematode resistance, estimation of quality and processing characters, screening for-

quality improvement, induction and identification of mutants and polyploids, distant hybridization and embryo rescue techniques.

Suggested Referances

Bhat K L 2001. Minor vegetables –untapped potential, Kalyani.

Indira P and Peter K V . 1984.Unexploited tropical vegetables. Kerala Agricultural University, Kerala.

Peter K v.(Ed) 2007-2008. Underutilised and underexploited Horticultural Crops. Vol. I-IV. New India Publishing Agency.

Prohens Jand Nuez F.2008, Vegetables I, Springer, USA.

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Rubatzky V E and Yamaguchi M (Eds).1997. World Vegetables: Principles, Production and Nutritive Values.Chapman and Hall.

Srivastava U, Mahajan R k, Gangopadyay K K, Singh M and Dhillon B S.2001 Minimal Descriptors of Agri –Horticultural Crops. Part II: Vegetable Crops, New Delhi.

VSC 615	**Improvement and Production Technology of Exotic Vegetables**	**1+1**

Theory

Present status and prospects of exotic vegetable crops cultivation; nutritional and medicinal values; climate and soil as critical factors in vegetable production; choice of varieties; nursery management; modern concepts in water and weed management; physiological basis of growth, yield and quality as influenced by chemicals and growth regulators; nutritional deficiencies, disorders and correction methods; different cropping systems; mulching; containerized culture for year round vegetable production; low cost polyhouse; net house production; crop modeling, organic gardening; vegetable production for pigments, evolution, distribution, cytogenetics, genetic resources, genetic divergence, types of pollination and fertilization mechanisms, sterility and incompatibility, anthesis and pollination, hybridization, breeding, inheritance pattern of traits, selection indices, genetics of spontaneous and induced mutations, problems and achievements of mutation breeding, ploidy breeding and its achievements, in vitro breeding; breeding techniques for improving quality and processing characters; breeding for stresses, mechanism and genetics of resistance, breeding for salt, drought; low and high temperature; toxicity and water logging resistance, breeding for pest, disease, nematode and multiple resistance, export and processing, of: Parsley, Parsnip, rhubarb, lettuce, Zucchini, leek, Celeary, artichoke, asparagus, Chinese cabbage, Bab corn, red cabbage, broccoli, cherry tomato.

Practicals

Nursery techniques; practices in exotic vegetables crops growing and organic gardening; diagnosis of nutritional and physiological disorders; analysis of physiological factors like anatomy; photosynthesis; light intensity in different cropping situation; assessing nutrient status, use of plant growth regulators; practices in herbicide application; estimating water requirements in relation to crop growth stages, maturity indices; production constraints; analysis of different cropping system in various situation like cold and hot set; vegetable waste recycling management; quality analysis ;marketing survey of the above crops; visit to vegetable and fruit malls and packing houses. Designing of breeding experiments, identification of male sterile plants and assay, screening techniques for abiotic stresses,

screening and rating for pest, disease and nematode resistance, estimation of quality and processing characters, screening for- quality improvement, estimation of heterosis and combining ability, induction and identification of mutants and polyploids, distant hybridization and embryo rescue techniques.

Suggested Referances

Bhat K L 2001. Minor vegetables –untapped potential, Kalyani.

Indira P and Peter K V. 1984. Unexploited tropical vegetables. Kerala Agricultural University, Kerala.

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VSC 616	**Biometrical Genetics**	**1+1**

Theory

Unit I: Measures of central tendency and dispersion, mean, mode median, Standard deviation, coefficient of variance, product moment correlation coefficient and regression coefficient.

Unit II: Mendelian traits vs polygenic traits - nature of quantitative traits and its inheritance - Multiple factor hypothesis - analysis of continuous variation; Variations associated with polygenic traits - phenotypic, genotypic and environmental - non-allelic interactions; Nature of gene action - additive, dominance, epistatic and linkage effects.

Unit III: Principles of Analylis of Variance (ANOVA) - Expected variance components, random and fixed models; Designs for plant breeding experiments – principles and applications; Genetic diversity analysis – metroglyph, cluster and D2 analyses - Association analysis - phenotypic and genotypic correlations; Path analysis and Parent - progeny regression analysis;

Unit IV: Discriminate function and principal component analyses; Selection indices - selection of parents; Simultaneous selection models- concepts of selection - heritability and genetic advance. Generation mean analysis;

Unit V: Mating designs- Diallel, partial diallel, line x tester analysis, NCDs; Concepts of combining ability and gene action; Analysis of genotype x environment interaction - adaptability and stability; Models for GxE analysis and stability parameters.

Practicals

Working out biometrical parameters: Standard deviation, coefficient of variance, product moment correlation coefficient, regression coefficient, Genotypic variance, phenotypic variance, GCV, PCV, Heritability, Genetic advance / gain, Path analysis, Chi-square Test for heterogeneity, fitness of test for expected genetic ratios and detection of linkage. Estimation of heterosis : standard, mid-parental and better-parental heterosis - Estimation of inbreeding depression - Generation mean analysis: Scaling test, Joint scaling test, Stability analysis.D2 analysis - Grouping of clusters and interpretation - Cluster analysis - Diallel analysis: Griffing's methods I and II – Diallel analysis: Hayman's graphical approach Diallel analysis: interpretation of results - NCD and their interpretations - Line

x tester analysis and interpretation of results. Use of computer software to work out above mentioned biometrical parameters.

Suggested Referances

Arunachalam, V., 1974, The fallacy behind the use of modified line x tester design. Indian J. Genet. Plant Breed., 34: 280-287.

Kaloo G. 1994. Vegetable Breeding. Vols. I-III. Vedams eBooks.

Eberhart, S.A. and Russell, W.A., 1966, Stability parameters for comparing varieties. Crop Sci., 6: 36-40.

Falconer D. S. and Mackay T. F. C., Introduction to Quantitative Genetics, 1998, Longman Publ.

Gardner, C. O., 1963, Estimation of genetic parameters in cross pollinated plants and their implications in plant breeding. Statistical Genetics Plant Breeding. NAS-NRS Washington. D. C. Publication., 982: 228-240

Griffing, B., 1956, Concept of general combining ability in relation to diallel crossing system. Aust. J. Bio. Sci., 9: 463-493.

Hayman, B.L., 1958, The separation of epistatic from additive and dominance variation in generation means. Heredity, 12: 371-390.

Hayman, B.L. and Mather, K., 1955, The description on genetic interaction in continuous variation. Biometrics, 11: 69-82.

Kempthorne, O., 1957, An introduction to genetic statistics. John Wiley and Sons, New York, pp. 408-711.

Mather, C., 1949, Biometrical Genetics. Metheun and Co., London.

Panse, V.G., 1957, Genetics of quantitative characters in relation to plant breeding. Indian J. Gen., 17(2): 318-328.

Ram HH. 2001. Vegetable Breeding. Kalyani.

Singh R. K. and Chaudhary B. D., 1996, Biometrical Methods in Quantitative Genetic Analysis, Kalyani Publishers, New Delhi

FLORICULTURE AND LANDSCAPING

Sl. No.	Course No.	Course Title	Credit Hours
Major courses (Minimum 12 credits)			
1	FLS 601*	Crop Regulation in Ornamental Crops	2+1
2	FLS 602*	Post Harvest Biology of Floricultural Crops	2+1
3	FLS 603	Speciality Flowers, Fillers and Cut Greens	1+1
4	FLS 604	Biotechnological Approaches in Floricultural Crops	2+1
5	FLS 605*	Advances in Landscaping	1+2
6	FLS 606	Vertical Gardening	1+1
7	FLS 607	Modern Approaches in Breeding of Floricultural Crops	2+1
8	FLS 608	Current Trends in Production Technology of Floricultural Crops	2+1
9	FLS 609	Recent Developments in Protected Cultivation of Floricultural Crops	2+1
10	FLS 610	Flori business Management	2+0
11	FLS 611	Advances in Production of Rose, Anthurium and Orchid Under Cover	2+1
12	FLS 612	Advances in Post Harvest Handling and Value Addition in Ornamental Crops	2+1
13	FLS 671	Qualifying Examination	0+4
14	FLS 681	Seminar-I	0+1
15	FLS 682	Seminar-II	0+1
16	FLS 683	Seminar-III	0+1
17	FLS 691	Research	0+70

*** Compulsory among major courses**

FLS 601	Crop Regulation in Ornamental Crops	2+1

Theory

Block 1: Basis of crop regulation

Unit I: Basis of flowering: Ecophysiological influences on growth and 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, physical, 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.

Practicals

- 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).

Suggested Referances

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, New York. 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 University Press. 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.

FLS 602	Postharvest Biology of Floricultural Crops	2+1

Theory

Block 1: Pre harvest 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., precook-ling, 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-colou0

rs 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, transgenic 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.

Practicals

- 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).

Suggested Referances

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.

FLS 603	Speciality Flowers, Fillers and Cut Greens	1+1

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, button chrysanthemum, Bird of Paradise, Ornamental banana, ornamental curcuma, gingers, wax flower, kangaroo paw, limonium, rice flower, alyssum etc.

Unit II: Fillers: Cultivation practices of fillers like gypsophila, solidago, lupins, daisy, *etc*.

Unit III: Cut greens: Cultivation practices of cut greens like anthurium, ferns, asparagus, , thuja, *Philodendron xanado*, bottle brush, golden melaluca, ornamental palms, cycas, dracaena, monestera, eucalyptus, ruscus, dianella, ferns *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.

Practicals

- 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 foliages (2)
- Exposure visits (2)
- Economics and Project preparation (2)

Suggested Referances

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.

FLS 604	Biotechnological Approaches in Floricultural Crops	2+1

Theory

Block 1: Scope of biotechnology

Unit I: Scope of biotechnology: Present status of biotechnology, tools techniques and role in floriculture industry.

Block 2: Cell, tissue and organ culture

Unit I: Micropropagation: 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, 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.

Practicals

- 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).

Suggested Referances

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.

FLS 605	**Advances in Landscaping**	**1+2**

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, bio-aesthetic 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 utilization, historical and archaeological garden sites, Permissions required for bigger projects, carbon sequestration, carbon credits etc.

Practicals

- Plant identification (2)
- Materials of garden design, Design making by different garden styles and types (1)
- Assessing site and plants adaptability for different locations (1)
- Way of designing a commercial landscape project (5)
- 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)
- Tariff barriers, APEDA regulations for auction houses, major markets.

Suggested Referances

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

FLS 606	**Vertical Gardening**	**1+1**

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.

Practicals

- 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)

Suggested Referances

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, 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.

FLS 607	Modern Approaches in breeding of Floricultural crops	2+1

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*.

Practicals

- *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)

Suggested Referances

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.

FLS 608	**Current Trends in Production Technology of Floricultural Crops**	**2+1**

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, micro irrigation, 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 crops: Advances in roses, chrysanthemum, tuberose, gladiolus, marigold, Crossandra. Jasmine, gerbera, carnation, orchids, anthuriums, lilum, lisianthes, limonium, gypsophylla, *etc.*

Block 2: Mechanization and Post harvest management

Unit I: Mechanization: automation, sensors, sowing and plantin devices, harvesting, grading and packing, 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.

Practicals

- Greenhouse management; Soil decontamination techniques (2);
- Microirrigation; Nutrition and fertigation (2);
- Special practices- bending, netting, pinching, disbudding, defoliation and chemical pruning, 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).

Suggested Referances

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.

FLS 609	Recent Developments in Protected Cultivation of Floricultural Crops	2+1

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 management in 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, asparagus sps, ferns *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 export marketing channels, regulations for auction houses, major markets *etc.*

Practicals

- 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.

Suggested Referances

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.

FLS 610	Flori Business and Management	2+0

Theory

Floriculture: Global and Domestic scenario, word export and import of flowers and ornamental plants, Recent trends, flower auctions: domestic and International trade of loose and cut flowers, Marketing channels and price spread in traditional and cut flowers. E-commerce in floriculture, Online information system dealing with e-floriculture, Rosebazar.com, Websites dealing with e-floriculture. Flower auctions in Holland, USA, UK, India *etc.* Floriculture and WTO, Documentation and indexing of flowers and ornamentals, Export standards for different flowers and ornamentals, Flower seed business. Dry flowers: Scenario in domestic and international market. Essential oil industry in India and abroad, Trend in landscape business, Nursery trade in India, Patent rights in relation to floriculture, Quarantine procedures for floriculture products, Import regulations for flowers, flower seeds and other ornamentals, Export regulations for floriculture items, Role of national agencies viz. NABARD, NHB, APEDA and others.

FLS 611	Advances in production of Rose, Anthurium and Orchid under Cover	2+1

Theory

Importance, climate and soil, planting and management, irrigation, nutrition, training, pruning, use of growth regulators, weed management, manipulation of flowering, harvesting, transport, storage and post harvest physiology under cover . Genetics and breeding to produce superior varieties, breeding for disease and pest resistance.

Practicals

Identification, classification and description of commercial species / types / varieties. Important methods of propagation, training and pruning. Manipulation of flowering. Use of growth regulators and herbicides. Experiments on post harvest physiology techniques. Crops: Rose, Orchid and Anthurium.

Suggested Reference:

L.C. De., *Value additions in flowers and orchids*.
Bruhl,P., *A guide to the orchids of Sikkim*
Maheshwari,J.K. *et.al., Orchids of India.*
S.C.Dey., *Pot culture of Roses*
Prasad.S., Singh D. and Kumar U., *Commercial Floriculture*
Gorak singh, K.V.Prasad., Rose- *A production manual*
B P Pal., The rose in India

FLS 612	Advances in Post Harvest Handling and Value Addition in Ornamental Crops	2+1

Theory

Importance and scope. Post harvest physiological and biochemical changes in ornamental. Maturity indices; harvesting, grading, bunching of cut-flowers; Factors affecting cut-flower longevity; Pretreatments for extending the vase life of cut flowers, pre-cooling, use of preservative solutions, growth regulators and other chemicals. Preparation of cut-flowers for market and transportation. Export requirement. Dutch auctioning system. Importance, opportunities and prospects of value addition in floriculture; national and global scenario. production and exports, supply chain management. Dry flower making including pot pourries, their uses and trade; extraction technology, uses, sources and trade in essential oils; aromatherapy; pigment and natural dyes extraction technology, sources, uses and trade. 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. Floral craft including bouquets, garlands, flower arrangements *etc*. tinting (artificial colouring) of flower crops; Women empowerment through value added products making.

Practicals

Maturity indices and harvesting; Equipments – grading, sorting, cleaning and preparation for marketing. Studies on vase life of flowers. 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, gulroghan, attar, pankhuri; Petal embedded handmade paper making,

floral craft including bouquets, garlands, flower arrangements etc.; tinting (artificial colouring) of flower crops. Visit to flower auction centre, flower market and essential oil extraction unit.

Suggested Referances

Varma and Anil., Post harvest technologies for commercial floriculture Punnuswami., Post harvest techniques and management of dry flowers.

Salunke, D.K., Bhatt and Desai., 1990. Post harvest Biotechnology offlowers and ornamental plants.

S.K. Bhattacharjee and L.C. De., 2005. Post harvest technology of flowers and ornamental plants

PLANTATION, SPICES, MEDICINAL AND AROMATIC CROPS

Sl. No.	Course No.	Course Title	Credit Hours
Major courses (Minimum 12 credits)			
1	PSM 601*	Advances in Production of Plantation and Spice Crops	3+0
2	PSM 602*	Advances in Production of Medicinal and Aromatic Crops	3+0
3	PSM 603*	Recent Breeding Approaches in Plantation, Spice, Medicinal and Aromatic Crops	3+0
4	PSM 604	Advanced Methods in Laboratory Techniques	1+2
5	PSM 605	Biotechnological Approaches in Plantation, Spice, Medicinal and Aromatic Crops	3+0
6	PSM 606	Abiotic Stress Management in Plantation, Spice, Medicinal and Aromatic Crops	2+1
7	PSM 607	Organic Spice and Plantation Crops Production	2+1
8	PSM 608	Marketing and Export of Plantation, Spice, Medicinal and Aromatic Crops	2+1
9	PSM 609	Processing and Value Addition of Plantation Crops	2+1
10	PSM 610	Processing and Value Addition of Spices	2+1
11	PSM 611	Genetic Resources Management of Medicinal, Aromatic, Dye and Pesticidal Plants (MADPS)	2+1
12	PSM 612	Production Technology of Dye and Pesticidal Plants	1+1
13	PSM 671	Qualifying Examination	0+4
14	PSM 681	Seminar-I	0+1
15	PSM 682	Seminar-II	0+1
16	PSM 683	Seminar-III	0+1
17	PSM 691	Research	0+70

*** Compulsory among major courses**

PSM 601	Advances in Production of Plantation and Spice Crops	3+0

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.

Unit II: 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, Crops BIS standards, domestic andtechniques, export protocols.

Export grades, modern packaging Coconut, Arecanut, Oil palm, Cashew, Coffee, Tea, Cocoa, Rubber, Black pepper, Cardamom, Ginger, Turmeric, Nutmeg, Cinnamon, Clove, Vanilla, Coriander, Fennel, Fenugreek, Ajwain,

Suggested Referances

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.

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Chadha KL. 2001. *Hand Book of Horticulture*. ICAR.

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Harler CR. 1963. *The Culture and Marketing of Tea*. Oxford Univ. Press.

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Kurian A and Peter KV. 2007. *Commercial Crops Technology*. New India Publ. Agency. Marsh AC, Moss MK and Murphy EW. 1977. *Composition of Food Spices and Herbs, Raw, Processed and Prepared*. Agric. Res. Serv. Hand Book 8-2. Washinton DC.

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Nybe EV, Mini Raj N and Peter KV. 2007. *Spices*. New India Publ. Agency. Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.

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Peter KV. 2001. *Hand Book of Herbs and Spices*. Vols. I-III. Woodhead Publ. Co., UK and CRC, USA.

Peter KV. 2002. *Plantation Crops*. National Book Trust.

Pillay PNR. 1980. *Handbook of Natural Rubber Production in India*. Rubber Research Institute, Kottayam. pp.668.

Ponnuswami *et al*. 2018. *Spices*. Narendra Publishing House, New Delhi

Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2007. *Management of Horticultural Crops*. Parts I, II. New India Publ. Agency.

Purseglove JW, Brown EG, Green CL and Robbins SRJ. 1984. *Spices*. Vols. I, II. Longman. Purseglove JW. 1968. *Tropical Crops–Dicotyledons*. Longman.

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.

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, Medicinal and Aromatic Plants Industrial Profiles. Routledge, UK.

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.

Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology* (Developments in Crop Science). Elsevier Science.

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.

Sharangi AB, Datta S and Deb, P. 2018. *Spices: Agrotechniques for quality produce*, April, Academic 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.Srivastava HC, Vatsaya and Menon KKG. 1986. *Plantation Crops–Opportunities and Constraints*. Oxford and IBH.Publishing House, New Delhi.

Thampan PK. 1981. *Hand Book of Coconut Palm*. Oxford and IBH. Varmudy V. 2001. *Marketing of Spices*. Daya Publ. House.

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*. ICA

PSM 602	Advances in Production of Medicinal and Aromatic Crops	3+0

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, *Digitalis* sp., *Commiphora* sp., Henbane, *Ocimum* sp., Centella, Bacopa, Saraca Safed musli and Valerian.
B. Aromatic crops: Palmarosa, Lemongrass, Citronella, Vetiver, Geranium, Artemisia, Mint, Eucalyptus, Rosemary, Thyme, Patchouli, Rose, Jasmine, Sandalwood, Lavender.

Suggested Referances

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.

Khan IA and Khanum A. 2001. *Role of Biotechnology in Medicinal and Aromatic Plants*. Vol.

IX. Vikaaz Publ.

Panda H. 2002. *Medicinal Plants Cultivation and their Uses*. Asia Pacific Business Press. Ponnuswami *et al*. 2018. *Medicinal Herbs and herbal cure*. Narendra Publishing House, New Delhi.

Prajapati ND, PaeroHit SS, 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.

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.

PSM 603	Recent Breeding Approaches in Plantation, Spice, Medicinal and Aromatic Crops	3+0

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, Coriander, Fennel, Fenugreek,Ajwain.

Medicinal crops: Senna, Periwinkle, Aswagandha, Isabgol Sarpagandha, Poppy, Glory lily, Medicinal coleus, *Mucuna pruriens*, Ocimum, *Centella asiatica*, *Bacopa monnieri*, *Aloe vera*.

c. Aromatic crops: Lemongrass, Palmarosa, Citronella, Vetiver, Mint, Sweet basil, Geranium, Patchouli, Davana, Rosemary, Thyme, Marjoram.

Suggested Referances

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.

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Chadha KL. 2001. *Hand Book of Horticulture*. ICAR.

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Kurian A and Peter KV. 2007. *Commercial Crops Technology*. New India Publ. Agency. Marsh AC, Moss MK and Murphy EW. 1977. *Composition of Food Spices and Herbs, Raw, Processed and Prepared*. Agric. Res. Serv. Hand Book 8-2. Washinton DC.

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Peter KV. 2001. *Hand Book of Herbs and Spices*. Vols. I-III. Woodhead Publ. Co., UK and CRC, USA.

Peter KV. 2002. *Plantation Crops*. National Book Trust.

Pillay PNR. 1980. *Handbook of natural rubber production in India*. Rubber Research Institute, Kottayam, 668pp.

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.

Ponnuswami V *et al.* 2018. *Blossom biology of Horticultural crops.* Narendra Publishing House, New Delhi.

Ponnuswami V *et al*. 2018. *Spices*. Narendra Publishing House, New Delhi

Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2007. *Management of Horticultural Crops*. Parts I, II. New India Publ. Agency.

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Purseglove JW, Brown EG, Green CL and Robbins SRJ. 1984. *Spices*. Vols. I, II. Longman. Ramachandra *et al*. 2018. *Breeding of Spices and Plantation crops*. Narendra Publishing House, New Delhi.

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PSM 604	Advanced methods in Laboratory Techniques	1+2

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 III: Value addition transportation.

Block 2: Spice Crops

Fixed oils, value added products, grading, storage

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.

Practicals

- 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.

Suggested Referances

Barche S. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi.

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Orhan I. 2012. *Biotechnological Production of Plant Secondary Metabolites*. Bentham Science Publishers.

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PSM 605	**Biotechnological Approaches in Plantation, Spice, Medicinal and Aromatic Crops**	**3 +0**

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, mbryo 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

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PSM 606	**Abiotic Stress Mangement in Plantation, Spice, Medicinal and Aromatic Crops**	**2+1**

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.

Practicals

- 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.

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PSM 607	Organic Spice and Plantation Crops Production	2+1

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.

Practicals

- 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.

Suggested Referances

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PSM 608	**Marketing and Export of Plantation, Spice, Medicinal and Aromatic Crops**	**2+1**

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

Practicals

- 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.

Suggested Referances

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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.

PSM 609	Processing and Value Addition of Plantation Crops	2+1

Theory

On – farm processing and the quality of finished products. Constraints in plantation sector. Prospects and scope for improvement. Consumer's preferences and requirements. Recent concepts in value addition and product diversification of plantation crops. (i) Coconut- Potential and scope of processing of fresh coconut. Processing for shelf stable products from coconut milk/ cream. Spray dried coconut milk powder def atted coconut powder, desiccated coconut, virgin coconut oil. Preservation of tender coconut water. Preservation of coconut inflorescence sap. Commercial production of toddy, jaggery, alcohol and vinegar. Latest methods in refining and de-odourizing of coconut oil. Solvent extraction of coconut oil. Coconut based foods-coconut chips, coconut biscuits, Nata-de-coco, coconut jam, coconut burfi, coconut honey. Coconut shell products, carvings, novelties and charcoal and activated charcoal. Coir manufacturing and coir industry in Karnataka, Geotextiles. (ii) Oil palm-Pilot processing, Quality characteristics of palm oil in comparison with coconut oil.(iii) Areca nut – Tender nuts : scope for manufacturing of diversified masticatory products. Utilization of by products like furfural and phenolics in industrial sector. Isolation and formulation of alkaloids for pharmaceutical uses. Diversified uses of areca spathe. (iv) Cashew nut – Small scale processing, hitech processing, grading, roasted nuts, flavoured nuts and other value-added products. Cashew apple: exploitation for production for unfermented beverages (juice, nectar, squash, syrup etc.) cashew apple pickle and fermented beverages (wine, alcohol, fenny). Scope of production of byproducts, viz, CNSL, testa tannins. (v) Cocoa – Improved methods of fermentation, drying and processing. Cocoa butter, cocoa powder and byproducts. Pilot manufacturer of chocolate. (vi) Coffee –Innovations in manufacturing of cherry coffee and powder. Characteristics of parchment coffee and its powder. Comparison of plain coffee vs. blended coffee (chicory blended). Advantages of specialty coffee. Decaffeinated coffee, Mysore Nuggets, Plantation A, Pea Berry, Extra Bold, Monsoonized Malabar, Washed Robusta coffee. (vii)Tea- Mechanical tea plucking. Orthodox and CTC tea. Specialty teas; Organic tea, Green tea, Oolong tea, white tea and other popular grades of tea. Chemistry of tea processing. (viii)Rubber: Methods in preservation and processing of latex. production of sheet rubbers and crepe rubbers. Studies on processing operations and machinery for Technically specified Rubber (TSR), Specialty Rubbers viz., Super processing rubbers, Constant Viscosity NR, Low Viscosity NR, Oil extended Natural Rubber (OENR), Graft Natural Rubber, Deproteinised Natural Rubber., Epoxidised Natural Rubber.

Practicals

Processing of raw materials of plantation crops in the Lab for preparation of novel products. Visits to progressive farmers' plots for learning recent trends in on-farm processing. Quality characterization of plantation products. Visits to the local and export markets for familiarizing the currently traded products and their grades. Visits to processing units and R and D divisions.

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Thampan PK. 1981. Handbook of Coconut Palm. Oxford & IBH.

PSM 610	Processing and Value Addition of Spices	2+1

Theory

Importance of on-farm processing, value addition and product diversification of spices. Adoption of improved on- farm processing methods. Cleaning and grading of harvested/ processed produce at farm level. Effects of pre- treatmentsviz., blanching, chemical treatments, better drying methods (solar, electric, LPG drying) , improved bleaching methods etc. on better physico- chemical qualities of productsLatest technologies in processing, value addition and product development of major spices viz., black pepper, cardamom (small and large), ginger, turmeric. Recent concepts in the processing of dried / de- hydrated spices, brining of fresh spices, frozen / freeze-dried spices, extraction of essential oils, oleoresins, super critical fluid extracts, essences, spice drops, encapsulated flavours, spice powders / curry powders, instant spices, spice pastes, extruded spices.

Modern methods in processing, value addition and product development of cinnamon, clove, nutmeg, Garcinia(kudampuli), allspice, tamarind. vanilla, coriander, cumin, fennel, fenugreek, celery, mustard, Quality up-gradation in spices and spice products. Production and certification for organic spices. Establishment of spices based processing units. Acquiring Logo, Certificates and License for internal trading and exports.

Practicals

Harvesting indices of spices for dehydrated spices, canning, freezing, freeze-drying, essential oils, oleoresins, ground spices, brining of spices and other products. Visits to progressive farms for exposure to newer methods in on- farm processing. Acquainting on- farm operations like, cleaning, drying, blanching, bleaching, grading. Visits to wholesale markets and export zones for familiarizing the export grades. Distillation of essential oils, extraction of oleoresins, dehydrated spices, brining of spices, spice powders, other extracts and products.Preparation of white pepper, dry ginger, dry

turmeric. Preparation of bleached products from spices. Physico chemical analysis on estimating the quality aspects of various spices. Visits to hi- tech processing units.

Suggested References

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PSM 611	**Genetic Resources Management of Medicinal, Aromatic, Dye and Pesticidal Plants (MADPS)**	**2+1**

Theory

Geographic distribution of MADPs and principles of evolution. Regions of plant diversity, Nuclear centers and mega gene centers-analysis of variation in plant populations-gene pool sampling in field, tree and vegetatively propagated MADPs-Plant diversity in Indian gene centers -MADPs exploration and germplasm collection - planning and logistics-plant exploration and exchange- plant quarantine principles, regulations plant quarantine systems in India. Components of germplasm evaluation, descriptors. Some practical considerations of germplasm evaluation -conservation of MADPs genetic resources, Concept of base and active collections, long and short term storage of MADPs, gene bank management, recent approaches and role of biotechnology in PGR conservation- documentation and data base management, cataloguing gene bank information. MADPs genetic resources management in India and in International perspective- utilization and achievements in major MADPs. Concepts of rarity, threatened, endangered and extinction in MADPs.

Practicals

Collection and identification of different medicinal and aromatic plants present in nature and preparation of herbarium. Botanical, phyto- chemical and galanicals groupings of MADPs. Classification of MADPs based on plant parts used. Detection of adulterants and substitutes. Ethno botanical studies in tribal areas. Planning and

layout of herbal gardens. Visit to herbaria,herbal gardens and important organisations engaged in collection and utilization of these plants.

PSM 612	Production Technology of dye and pesticidal plants	1+1

Theory : Introduction, historical background, present status of production and utilization. Origin and distribution, species, varieties, economic parts. Ecology, crop management harvesting and extraction of dye and pesticides of plants viz., annatto, Mehandi, Indigo, Indian Maddar, Marigold, sappan, Pyrethrum, Red sanders, Neem, Sweet flag, Adhatoda, Clerodendron inerme, Vitex nigondu.

Practicals : Study of botanical characteristics of different species of dye and pesticidal plants. Study of propagation and nursery techniques. Study of pests and diseases and their management. Extraction and quantification of dyes and pesticide contents.

POSTHARVEST MANAGEMENT

Sl. No.	Course No.	Course Title	Credit Hours
Major courses (Minimum 12 credits)			
1	PHM 601*	Ripening and Senescence of Fruits and Vegetables	1+1
2	PHM 602*	Recent Trends in Food Preservation	1+1
3	PHM 603	Management and Utilization of Horticultural Processing Waste	3+0
4	PHM604*	Supply Chain Management of Perishables	2+0
5	PHM 605	Export Oriented Horticulture	1+0
6	PHM 606	Food Additives	1+1
7	PHM 607	Advances in Processing of Plantation, Spices, Medicinal and Aromatic Plants	3+0
8	PHM 608	Value Addition in Ornamental Crops	1+1
9	PHM 609	Novel Processing Technologies for Horticultural Produce	2+1
10	PHM 610	Advances in Packaging Technology of Horticultural Produce	1+1
11	PHM 611	Designing of Horticulture Processing Plant	1+1
12	PHM 612	Advances in Laboratory Techniques in Post Harvest Technology	1+2
13	PHM 613	Texture and Rheological Properties of Food Products	1+1
14	PHM 614	Nanotechnology and its Application in Post Harvest Technology	2+0
15	PHM 615	Food Laws, Regulations and Quality Management	2+0
16	PHM 616	Advances in Wine Technology	1+1
17	PHM 617	Food Enzymes and Horticulture Waste Utilization	1+1
18	PHM 618	New Product Development in Horticultural Produce	1+1
19	PHM 619	Food Chemistry	1+1
20	PHM 620	Food Toxicology	1+1
21	PHM 671	Qualifying Examination	0+4
22	PHM 681	Seminar-I	0+1
23	PHM 682	Seminar-II	0+1
24	PHM 683	Seminar-III	0+1
25	PHM 691	Research	0+70

*** Compulsory among major courses**

PHM 601	Ripening and Senescence of Fruits and Vegetables	1+1

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.

Practicals

- 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, celluloses, pectin methyl esterases, polygalacturonase, etc.

Suggested Referances

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.

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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.

PHM 602	Recent Trends in Food Preservation	1+1

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 and FDA.

Practicals

- 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.
- Enumerate the hurdle approaches in food processing;
- Detection of microbes in each hurdle. Study of shelf life of fresh cut produce in each 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 – Pros and cons;
- Visit to advanced food processing unit;
- Visit to SCFE unit.

Suggested Referances

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.

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Tewari G and Juneja V. 2007.Advances in thermal and nonthermal food. Blackwell Publishing, ISBN 9780813829685.

PHM 603	Management and Utilization of Horticultural Processing Waste	3+0

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 anaerobic waste treatment processes.

Block 2: Valorization 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.

Suggested Referances

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.

PHM 604	Supply Chain Management of Perishables	2+0

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/ ApniMandi, etc. based on regional importance.

Suggested Referances

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.

PHM 605	**Export Oriented Horticulture**	**1+0**

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-addedproducts, Postharvest management for export including packaging andcool chain; HACCP, Codex alimentations, ISO certification; APEDAand its role in export, WTO and its implications, sanitary and phyto-sanitary measures. Codex norms and GAP and SOP for export ofmajor horticultural crops from India.

Block 2: Export related policies

Unit I: Exportimplications: Export of seed and planting material; implications

Unit II: Export oriented regulatory issues: Agriculture Export Policy, Export Procedure, EXIM policy, APMC act, Action centers, Regulatory issues of Ministry of Commerce, GoI .

Suggested Referances

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.

PHM 606	Food Additives	1+1

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, LD50 value.

Practicals

- 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.

Suggested Referances

Branen AL, Davidson PM, Salminen S and Thorngate 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.Methods of Analysis of Food Components and Additives, CRC Press, ISBN 9780849316470.

Taylor AJ. andLinforth 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.

PHM 607	Advances in Processing of Plantation, Spices, Medicinal and Aromatic Plants	3+0

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 forcoir 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, effleurage, 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 II: 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.

Suggested Referances

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 FereidoonShahidi. 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.

PHM 608	Value Addition in Ornamental Crops	1+1

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 handmade 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.

Practicals

- 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 watergulroghanattar, pankhuri;
- Petal embedded handmade paper making;
- Floral craft including bouquets, garlands, flower arrangements, etc.;
- Tinting (artificial colouring) of flower crops.

Suggested Referances

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 ornamental plants. NayaProkash, Kolkata.

PHT 609	Novel Processing Technologies for Horticultural Produce	2+1

Theory:

UNIT I: Recent advances in processing technologies: aseptic processing, individual quick freezing and cryogenic freezing, membrane technology, extrusion cooking, vacuum frying, ohmic heating, microwave processing and dielectric heating.

UNIT II: Non thermal processing -irradiation, pulsed electric field, magnetic fields, pulsed light treatment, high pressure processing, ultrasound, linear induction electron accelerator (LIEA), SCFE, ozonation, minimal processing and hurdle technology.

UNIT III: Functional foods and nutraceuticals, Enzymes and their application in food industry.

UNIT IV: Principles of food biotechnology, genetic modification of microorganisms in food industry (lactic acid bacteria, yeasts and moulds), production of high valued food products viz. enzymes, organic acids, SCP, nutritional additives, flavours, pigments.

Practicals:

- Methods of food fortification.
- Determination of thermal resistance of bacteria TDT and TDP.
- Determination of thermal death curve.
- Thermal process calculations.
- Study of problems associated with new technologies.
- Group discussions.
- Advances in fermentation technology.
- Recent trends in freeze preservation.
- Development of new products and value addition.

- Visit to processing industries.

Suggested Referances

Barbosa-Canovas., 2002.Novel Food Processing Technologies.CRC. Press

Bhutani RC., 2003. Fruits and vegetables preservation.Biotech Books, Delhi.

Da-Wen Sun., 2006. Thermal food processing: new technologies and quality issues. CRC/Taylor & Francis.

Gould, G.W., 2000. New Methods of Food Preservation.CRC.springer science PHILIP R., 2001. Thermal technologies in food processing.CRC Press.

Ramaswamy, H. and Marcotte, M., 2006. Food Processing: Principles and Applications. Taylor & Francis.

Rajarathnam, S. and Ramteke, R. S., 2011., Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

PHM 610	Advances in Packaging Technology of Horticultural Produce	1+1

Theory

UNIT I: Active packaging techniques, Intelligent packaging techniques, novel packaging techniques, Oxygen scavenging technology, Ethylene scavenging technology, Carbon dioxide and other scavengers, Antimicrobial food packaging: development of antimicrobial packaging system, Factors affecting the effectiveness of antimicrobial packaging.

UNIT II: Non-migratory bioactive polymers (NMBP) in food packaging, Advantages of NMBP, limitations, inherently bioactive synthetic polymers: types and applications, Polymers with immobilized bioactive compounds.

UNIT III: Time-temperature indicators (TTIs), Defining and classifying TTIs, Requirements for TTIs, The development of TTIs, Current TTI systems, Maximizing the effectiveness of TTIs, Using TTIs to monitor shelf-life during distribution, Using TTIs to optimize distribution and stock rotation.

UNIT IV: Packaging-flavour interactions, Factors affecting flavour absorption, role of the food matrix, role of differing packaging materials, Case study: packaging and lipid oxidation, Modeling flavour absorption, Packaging–flavour interactions and active packaging, Novel MAP applications for fresh-prepared produce, Novel MAP gases, Testing novel MAP applications, Applying high O2 MAP. Recycling of packaging materials.

Practicals

- Identification of plastic film material - specific gravity test, melting and odour test, burning test, solubility test.
- General quality control tests carried out on papers, plastic films, foils and multilayered films - chloride test, pH test, moisture content, tensile test, bursting test, tearing resistance, puncture and other impact tests, insect penetration test, heat sealing strength, toxicity test, colour migration test.
- Testing of lacquered tin plate sheets;
- Measurement of tin coating weight by Clarke's method.
- Determination of GTR and WVTR in different packaging materials,
- Use of oxygen and ethylene scavengers in packaging of fresh fruits,
- Application of anti-microbial packaging for moisture sensitive foods,
- Evaluation of pesticide residue migration from package to food,
- Application of MAP and active packaging in selected foods,
- Determination of oxidative changes in packaged foods, comparative evaluation of flexible and rigid packages for fragile foods and packaging of foods under inert atmosphere.
- Prediction of shelf life of foods, selection and design of packaging material for different foods.

Suggested References:

Ahvenainen , R., 2001. Novel Food Packaging Techniques.CRC.

Rajarathnam, S. and Ramteke, R. S., 2011., Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

PHM 611	Designing of Horticulture Processing Plant	1+1

Theory

UNIT I: Plant design concepts and general design considerations; plant location – location factors and their interaction with plant location, location theory models, computer aided selection of the location; feasibility analysis and preparation of feasibility report; plant size- factors affecting plant size and their interactions, estimation of break even and economic plant size;

UNIT II: Product and process design, process selection; process flow charts, computer aided development of flow charts, equipment selection including economic analysis of equipment alternatives; plant layout including computer aided development and evaluation, layout symbols; planning and design of services facilities, human resource, product packaging and marketing system;

UNIT III: Hygienic design aspects and workers safety; functional design of plant building and selection of building materials; estimation of capital investment, analysis of plant costs and profitability; management techniques in plant design including applications of network analysis; preparation of project report and its appraisal.

Practicals

- Each student will be asked to select a food processing plant system and develop a plant design report which shall include product identification and selection.
- Site, estimation of plant size, process and equipment selection, process flow sheeting, plant layout and its evaluation.
- Visit to food parks.

Suggested References

ANTONIO, L. G. AND GUSTAVO, V. BARBOSA-CANOVAS., 2005.Food Plant Design.Taylor and Francis.

GEORGE, D. S. AND ATHANASIOS, E. K., 2002. Hand book of food processing equipment. Kluwer Academic

ZACHARIAS, B. M. AND GEORGE, D. S., 2003.Food Process Design. Marcel Dekker.

ZACHARIAS B. M. AND GEORGE D. S., 2007.Food plant economics. 2007. CRC Press. London

RAJARATHNAM, S. AND RAMTEKE, R. S., 2011. Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

PHM 612	Advances in Laboratory Techniques in Postharvest Technology	1+2

Theory:

UNIT I: Importance of quality of processed foods. Principles of food quality assurance. Introduction to quality evaluation. Food grades, standards, laws and regulations.

UNIT II: Sampling procedure for food analysis. Advances in techniques of food analysis for carbohydrates, organic acids, vitamins, polyphenols, flavonoids, minerals, anthocyanins, enzymes; Rheological techniques and instrumentation used in food industry.

Practicals

- Determination of browning and associated reactions in processed foods and their implications. Analysis of food additives like food colour, antioxidants, emulsifier, etc. Analysis of pesticide residues, metallic contaminants, aflatoxin. Analysis of food flavours. Quality analysis of processed fruits and vegetables, coffee, tea and spices. Identification and enumeration of microbial contaminants.
- Principles of chromatography (GC, GCMS, HPLC, LCMS), spectrophotometry (Atomic absorption spectrophotometer, ICAP spectrophotometer), ICP-MS, ICPOES, NMR, ESR, amino acid analyser, flame photometry, electrophoresis, colour measurement in foods, IRGA, Radio- isotopic techniques. Nondestructive quality evaluation (NDQE) - E-nose, E-tongue, machine vision.electrophoresis. 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.

Suggested References:

AOAC International., 2003. Official methods of analysis of AOAC International.17th Ed. Gaithersburg, MD, USA, Association of Analytical Communities. AVI Publ.

LEENHEER, A. P., LAMBERT, W. E. AND BOCXLAER, J. F., 2000.ModernChromatographic Analysis of Vitamins.3rd Ed. Marcel Dekker.

MASLOWITZ , H., 2000. Applied sensory analysis of food .Vol.I & II.CRC Press.

RANGANNA, S., 2001.Handbook of Analysis and Quality Control for Fruit and Vegetable Products. 2nd Ed. Tata-McGraw-Hill

TAYLOR, A., 2002. Food Flavour Technology.Sheffield Academic Press.

RAJARATHNAM, S. AND RAMTEKE, R. S., 2011, Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

PHM 613	Texture and Rheological Properties of Food Products	1+1

Theory:

UNIT I: Concept of Rheology- definition of ideal bodies, rheological models, viscoelastic characterization, creep relaxation dynamics;

UNIT II: Methods of introducing non-linearity in models; complex modulus; rheological characterization and modeling for various liquid foods, flow curves; dynamic behaviour of viscoelastic bodies, frequency response;

UNIT III: Viscometry- back extrusion viscometry and mixer viscometry; interaction between human organ responses and machine measurements in food product quality characterization; rheological responses and equipment design.

Practicals:

Laboratory exercises on basic rheological parameters of food materials creep and stress relaxation tests on selected food materials, measurement of viscosity of liquid foods using various devices at various temperatures and solid concentrations, measurement on

food texture using INSTRON machine, measurement of load deformation characteristics of food materials using INSTRON machine, analysis of available data on rheological properties.

Suggested References:

FAITH, A. M., 2001.Understanding Rheology.Oxford University Press.

FIGURA, L. O. AND TEIXEIRA, A. A., 2007.Food Physics. Springer Publ. MALCOLM, C. B., 2002. Food texture and viscosity.Academic Press.

RAO, M. A., 2007. Rheology of fluids and semisolid fluids – principles and applications. Springer

JOSHI, V. K., 2006. Sensory science, principles and application in food evaluation.ATPA pub.ISBN 8183210538.

RAJARATHNAM, S. AND RAMTEKE, R. S., 2011., Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

PHM 614	Nanotechnology and its Application in Postharvest Technology	2+0

Theory

UNIT I: Nanotechnology- Definition, Concepts-Top down and Bottom up, History and introduction, growth of nanofood market, nanotechnology in India, special features of nanotechnology, applications of nanotechnology in food and agriculture, concept of nanofood.

UNIT II: Applications of nanotechnology in packaging, anti microbial nature, O2 scavenging, nano sensors and smart packaging, nano composite based package, nano based biodegradable package, nano food additives.

UNIT III: Nanoencapsulation and food fortification, probiotics, nanosensors for microbial detection, commercial products, safety laws and regulation.

Suggested references:

HUANG, Q., 2012, Nanotechnology in the Food, Beverage and Nutraceutical Industries, 1st Edn, Woodhead Publishing Series in food science, technology and nutrition.

LYNN, J. F., WILLEM N, ARNOUT, F. AND FRANS, K., 2011. Nanotechnology in the Agri-Food Sector.

DEBASIS, B., MANASHI B., HIROYOSHI, M. AND FEREIDOON, S., 2013. Bio-Nanotechnology: A Revolution in Food, Biomedical and Health Sciences.

SINGH, H. P., KUMAR, A. AND PARTHASARTHY, V. A., 2013. Nanotechnology inagriculture- Advances in Horticulture Biotechnology

RAJARATHNAM, S. AND RAMTEKE, R. S., 2011., Advances in preservation and processing technology of fruits and vegetables. By NPA pub

PHM 615	Food Laws, Regulations and Quality Management	2+0

Theory:

UNIT I:Horticulture food chain, Hazards – biological, chemical, physical; Quality assurance system and food safety; Challenges and opportunities for developing country for exports.

UNIT II: Reasons for implementing food safety and quality standards; Sampling procedures and plans; Food Safety and Standards Act, 2006; Strategies for compliance with international Agri-food standards: GAP, GMP, GHP, GLP, TQM, Sanitary and Phyto-sanitary (SPS) certification, statistical processed control, quality auditing.

UNIT III: Design and implementation of HACCP system; Steps in the risk management process; Traceability in food supply chains; microbial and biochemical analysis of food.

UNIT IV: Various organizations dealing with inspection, traceability and authentication, certification and quality assurance -FSSAI, APEDA. Indian and International quality systems and standards like Codex Alimentarius,EurepGAP, ISO, BIS, BRC, SQF. Consumer perception of safety; Ethics in food safety. Export/Import policy by Govt. of India.

Suggested References:

LUNING, P. A., DEVLIEGHERE, F. AND VERHE, R., 2007.Safety in the agri-foodchain.Wageningen Academic Publishers.

PETER, K. V., 2008. Basics in Horticulture.New India Publ. Agency.

RANGANNA, S., 2001.Handbook of Analysis and Quality Control for Fruit and Vegetable Products.2nd Ed. Tata-Mc Graw-Hill.

MAHINDRU, S. N., 2004. Food Safety: Concepts and Reality. APH Publ. Corp.

RAJARATHNAM, S. AND RAMTEKE, R. S., 2011., Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

PHM 616	Advances in Wine Technology	1+1

Theory:

UNIT I:Types and present status of alcoholic beverages; present status of wine grape and wine industryin India and world; production technology of wine grapes; maturity index; post-harvest handling and storage of wine grapes; technology of wine making; classification of wines; production of sparkling wine; factors affecting the quality of wine production; stuck and malolactic fermentation, monitoring and controlling of fermentation parameters of wine.

UNIT II: Ageing of wine - oak wood barrels and oak wood chips. Application of colours and additives in grape wine production.Production of wine from horticulture crops other than grapes.Packaging technology, labeling & storage of wines.

UNIT III: Sensory evaluation of wine, methods of sensory evaluation, basic taste of wine; taste of bitterness, acidity, salt, sweetness, glycerol and alcohol on tongue with reference to sensory response and perception.

UNIT IV: International regulatory standards and guidelines for wine production and marketing; New concept of wine production - organic, biodynamic wine etc. Application of good hygienic and manufacturing practices in wine production.Wine analysis and quality control.Wine parks and nodal agencies for establishment of wine parks.

Practicals:

- Design, layout and operation of fermenters,
- Types of fermenters.: Destemer, Crusher, Pneumatic/ hydraulic press, Screw pumps, Fermentation tanks with cooling jackets/ cooling system, Filters, Vaccumized bottling plants, Wine cold stabilization tanks, Water softening plant, oak wood vats and barrels for maturation of wine.
- Determination of pH and TSS of grape juice and wine,
- Analysis of wine with respect to titrable acidity, alcohol (ethanol) percentage, volatile acidity, free SO2 in wine / juice / must, total SO2 in wine;
- Protein stability test / Heat stability test of wine;
- Tartarate and bitartrate stability test / Cold stability test of wine.
- Determination of acetaldehyde content of wine by titrimetric method.
- Determination of phenol content of wine by titrimetric method.
- Sensory analysis of hydrogen sulphide and Mercaptans in wine.
- Methanol estimation by Gas chromatography.
- Estimation of reducing and total sugar by copper reduction technique.
- Determination of total tannin content by visible spectrometry.

- Evaluation of different sensorial quality parameters of wine.
- Visit to wine grapes orchard, winery and wine Park.

Suggested References:

GLAUDIO, D. AND FORMICA, J. V., 2001.Wine Microbiology.Science and Technology.

RONALD, S. J., 2008. Wine Science, 3rd Edition .Academic Press.

RAJARATHNAM, S. AND RAMTEKE, R. S., 2011., Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

PHM 617	Food Enzymes and Horticulture Waste Utilization	1+1

Theory

UNIT I: Enzymes – classification, properties, characterization, kinetics and immobilization; fermentative production of enzymes (amylases, proteases, cellulases, pectinases, xylanases, lipases) used in food industry and their downstream processing.

UNIT II: Enzymes as processing aids: fruit juices-cell wall degrading enzymes for liquefaction, clarification, peeling, debittering, decolourization of very dark colored juices such as anthocyanins; oxidases as replacers of chemical oxidants; synergistic effect of enzymes; Enzyme processing for flavours i.e. enzyme-aided extraction of plant materials for production of flavours, production of flavour enhancers such as nucleotides.

UNIT III: COD and BOD. Bioremediation.Waste characteristics – sampling methods, analysis and standards for waste discharge.Survey and nature of waste from processing industry and their present disposal methods.Methods for waste and waste water reduction.In plant modifications and innovative processes.

UNIT IV: Recovery of useful materials from waste, viz., colour, essence, pectin, oils, etc. Utilization of waste and by-products – new products, animal feed and single cell protein. Technology of treatments of waste effluent from fruit and vegetable industries. Immobilized bioreactor in waste treatment.Anaerobic bioreactor and energy production.Economics of effluent management.

Practicals:

- Assay of enzymes for activity, specific activity, kinetics, stability (temperature, pH and storage); Extraction and clarification of juices using enzymes

Suggested Referances

WHITEHURST, R. AND LAW, B., 2002.Enzymes in Food Technology.Blackwell Publ.

VERMA, L. R. AND JOSH, V. R., 2000.Post harvest technology of fruits and vegetables - handling, processing, fermentation and waste management. Vol-2. Indus Publishing company.

IOANNIS, S. A., 2007.Waste Management for the Food Industries.

RAJARATHNAM, S. AND RAMTEKE, R. S., 2011., Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

NEESER, J. R. AND GERMAN, B. J., 2004.Bioprocesses and Biotechnology for Nutraceuticals.Chapman & Hall.

ROBERT, E. C., 2006. Handbook of Nutraceuticals and Functional Foods.2nd Ed. Wildman.

SHI, J.(ED)., 2006. Functional Food Ingredients and Nutraceuticals: Processing technologies..CRC.

WEBB, G. P., 2006. Dietary Supplements and Functional Foods.Blackwell Publ.

RAJARATHNAM, S. AND RAMTEKE, R. S., 2011., Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

PHM 618	New Product Development in Horticultural Produce	1+1

Theory

UNIT I: Concept of product development, product success and failure, factors for success, process of product development, managing for product's success. Innovation strategy - possibilities for innovation, building up strategy, product development programme. Social trends as a frame work in new product innovation.

UNIT II: Types of products – fast foods, fabricated foods, convenience foods etc, The product development process - product strategy, product design and process development, product commercialization, product launch and evaluation.

UNIT III: The knowledge base for product development technology – knowledge of functional aspects of horticultural produce for product development, knowledge management, knowledge for conversion of product concept to new product, technological knowledge (product qualities, raw material properties, processing, packaging requirement, distribution and marketing).

UNIT IV: Role of consumers in product development - consumer behaviour, food preferences, avoiding acceptance, integration of consumer needs in product development and sensory needs. Managing the product development process, improving the product development process –

key message, evaluating product development, innovative matrices, striving for continuous improvement, Improving success potential of new products, market exploration and acquisition, Legal aspects of new product launch.

Practicals

- Market survey for identification of new horticultural crop based products.
- Assessing new products for their novelty.
- Locating new product opportunities,
- Assessment of raw materials availability,
- Laboratory exercise for development of a new product, analyzing the product for organoleptic and storage quality.
- Objective quality of new products.
- Testing the product for consumer acceptability.
- Planning of requirements for manufacture of new products in industry,
- Positioning of product in market, Launching and market evaluation.
- Input output analysis, Cost analysis for new products.

Suggested References

EARLE AND EARLE 2001.Creating New Foods. Chadwick House Group.

EARLE, R. AND ANDERSON A,. 2001. Food Product Development. Woodhead Publ.

FULLER,. 2004. New Food Product Development - from Concept to Market Place. CRC.

RAJARATHNAM, S. AND RAMTEKE, R. S., 2011., Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

PHM 619	Food Chemistry	1+1

Theory

UNIT I: Enzymes, minerals, phenolics, flavonoids, colourants, flavours, chemical additives, food contamination and toxic substances. Interaction of constituents in food systems; changes during storage and processing; browning reactions in foods.

UNIT II: Chemistry of fruits, vegetables, essential nutrients- sources, functions, deficiency diseases; requirements and recommended dietary allowances.

Practicals:

- Determination of peroxidase and catalase activity.
- Comparison of different methods for moisture determination in food samples.
- Test for presence of carbohydrates, and proteins.
- Identification of gums.
- Estimation of ash and minerals,
- Determination of fat and protein content,
- Determination of NEB,
- Determination of total carotenoids;
- Determination of reducing and total sugars,
- Determination of rancidity.
- Determination of crude and dietary fibre.

Suggested references

BAMJI, M. S., RAO, N. A. AND REDDY, V., 2003. Textbook of Human Nutrition.Oxford & IBH.

BAYNES, J. W., MONNIER, V. M., AMES, J. M. AND SUZANNE, R., 2005. TheMaillard Reaction: Chemistry at the Interface of Nutrition, Aging, and Disease Thorpe. Annals of the New York Academy of Science.

RAJARATHNAM, S. AND RAMTEKE, R. S., 2011., Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

PHM 620	Food Toxicology	1+1

Theory

UNIT I: Definition, scope and general principles of food toxicology; manifestation of toxic effects; classification of food toxicants; factors affecting toxicity of compounds; methods used in safety evaluation-risk assessments.

UNIT II: Ant nutritional factors, Toxicants and allergens in foods derived from plants, animals, marine, algae & mushroom; food microbial toxins and food pathogens; Food Poisoning, food borne infections and disease.

UNIT III: Derived Food toxicants- Processing & Packaging; Toxicants generated during food processing such as nitrosamines, acrylamide, benzene, dioxins and furans; persistent organic pollutants.

UNIT IV: Toxicology & food additives; Toxicological aspects of nutrient supplements; Chemicals from processing such as fumigants, chlorinated solvents, autoxidation products, carcinogens in smoked foods and pyrolysis, agrochemicals; heavy metals; intentional and unintentional additives; food adulteration.

Practicals

- Protocol for detection & quantification of toxins in food,
- Detection of pesticide residues, antibiotic residues, hormones and heavy metals;
- Analysis of microbial and plant toxins; Immunoassays.
- Detection of food adulterants.

Suggested Referances

SHABBIR, S., 2007.Food Borne Diseases. Humana Press.

RAJARATHNAM, S. AND RAMTEKE, R. S., 2011., Advances in preservation and processing technology of fruits and vegetables. By NIPA pub

ENTOMOLOGY

Sl. No.	Code	Course	Credit Hours
Major courses (12 credits)			
1.	ENT 601	Insect Phylogeny and Systematics	1+2
2.	ENT 602	Insect Physiology and Nutrition	2+1
3.	ENT 603	Insect Ecology and Diversity	2+1
4.	ENT 604	Insect Behavior	1+1
5.	ENT 605*	Bio-inputs for Pest Management	2+1
6.	ENT 606*	Insect Toxicology and Residues	2+1
7.	ENT 607	Plant Resistance to Insects	1+1
8.	ENT 608	Acarology	1+1
9.	ENT 609	Molecular Entomology	1+1
10.	ENT 610	Integrated Pest Management	2+0
11.	ENT 671	Qualifying Examination	0+4
12.	ENT 681	Seminar – I	0+1
13.	ENT 682	Seminar – II	0+1
14.	ENT 683	Seminar – III	0+1
15.	ENT 691	Research	0+70

ENT 601	Insect Phylogeny and Systematics	1+2

Theory

Unit I

Detailed study of three schools of classification- numerical, evolutionary and cladistic. Methodologies employed. Development of phenograms, cladograms, molecular approaches for the classification of organisms. Methods in identification of homology. Species concepts, speciation processes and evidences. Zoogeography.

Unit II

Study of different views on the evolution of insects- alternative phylogenies of insects: Kukalova Peck and Kristensen. Fossil insects and evolution of insect diversity over geological times.

Unit III

Detailed study of International Code of Zoological Nomenclature, including appendices to ICZN; scientific ethics. Nomenclature and documentation protocols and procedures; report preparation on new species; deposition of holotypes, paratypes, and insect specimens as a whole in national and international repositories – requirements and procedures.

Unit IV

Concept of Phylocode and alternative naming systems for animals. A detailed study of selected representatives of taxonomic publications – small publications of species descriptions, works on revision of taxa, monographs, check lists, faunal volumes, etc. Websites related to insect taxonomy and databases. Molecular taxonomy, barcoding species and the progress made in molecular systematics.

Practicals

- Collection, curation and study of one taxon of insects- literature search, compilation of a checklist, study of characters, development of character table, and construction of taxonomic keys for the selected group
- Development of descriptions, photographing, writing diagrams, and preparation of specimens for "type like" preservation, Submission of the collections made of the group
- Multivariate analysis techniques for clustering specimens into different taxa, and development of phenograms
- Rooting and character polarization for developing cladograms and use of computer programmes to develop cladograms.

Suggested Referances

CSIRO 1990. The Insects of Australia: A Text Book for Students and Researchers. 2nd Ed. Vols. I and II, CSIRO. Cornell Univ. Press, Ithaca.

Dakeshott J and Whitten MA. 1994. Molecular Approaches to Fundamental and Applied Entomology. Springer-Verlag, Berlin.

Freeman S and Herron JC. 1998. Evolutionary Analysis. Prentice Hall, New Delhi.

Hennig W. 1960. Phylogenetic Systematics. Urbana Univ. Illinois Press, USA.

Hoy MA. 2003. Insect Molecular Genetics: An Introduction to Principles and Applications. 2nd Ed. Academic Press, New York.

Mayr E and Ashlock PD. 1991. Principles of Systematic Zoology. 2nd Ed. McGraw Hill, New York.

Mayr E.1969. Principles of Systematic Zoology. McGraw-Hill, New York.

Quicke DLJ. 1993. Principles and Techniques of Contemporary Taxonomy. Blackie Academic and Professional, London.

Ross HH. 1974. Biological Systematics. Addison Wesley Publ. Co., London.

Wiley EO. 1981. Phylogenetics: The Theory and Practices of Phylogenetic Systematics for Biologists. Columbia Univ. Press, USA.

ENT 602	Insect Physiology and Nutrition	2+1

Theory

Unit I

Physiology and biochemistry of insect cuticle and moulting process. Biosynthesis of chitin, chitin-protein interactions in various cuticles, hardening of cuticle.

Unit II

Digestive enzymes, digestive physiology in phytophagous, wood boring and wool feeding insects, efficiency of digestion and absorption, role of endosymbionts in insect nutrition, nutritional effects on growth and development; physiology of excretion and osmoregulation, water conservation mechanisms.

Unit III

Detailed physiology of nervous system, transmission of nerve impulses, neurotransmitters and modulators. Production of receptor potentials in different types of sensilla, pheromones and other semiochemicals in insect life, toxins and defense mechanisms.

Unit IV

Endocrine system and insect hormones, physiology of insect growth and development-metamorphosis, polymorphism and diapause. Insect behaviour in IPM- Concept of super-normal stimuli and behavioural manipulation as potential tool in pest management, use of semio-chemicals, auditory stimuli and visual signals in pest management.

Practicals

- Preparation of synthetic diets for different groups of insects
- Rearing of insects on synthetic, semi-synthetic and natural diets
- Determination of co-efficient of utilization
- Qualitative and quantitative profile of bio-molecules: practicing analytical techniques for analysis of free amino acids of haemolymph
- Zymogram analyses of amylase
- Determination of chitin in insect cuticle
- Examination and count of insect haemocytes.

Suggested Referances

Ananthkrishnan TN. (Ed.). 1994. Functional Dynamics of Phytophagous Insects. Oxford and IBH, New Delhi.

Bernays EA and Chapman RF. 1994. Host-Plant Selection by Phytophagous Insects. Chapman and Hall, London.

Kerkut GA and Gilbert LI. 1985. Insect Physiology, Biochemistry and Pharmacology. Vols. IXIII. Pergamon Press, Oxford, New York.

Muraleedharan K. 1997. Recent Advances in Insect Endocrinology. Association for Advancement of Entomology, Trivandrum, Kerala.

Rockstein, M. 1978. Biochemistry of Insects, Academic Press.

Simpson, SJ. 2007. Advances in Insect Physiology, Vol. 33, Academic Press (Elsevier), London, UK.

ENT 603	Insect Ecology and Diversity	2+1

Theory

Unit I : Characterization of distribution of insects- Indices of Dispersion, Taylor's Power law. Island Biogeography. Population dynamics- Life tables, Leslie Matrix, Stable age distribution, Population projections. Predator-Prey Models- Lotka-Volterra and Nicholson-Bailey Model. Crop Modeling- an introduction.

Unit II : Insect Plant Interactions. Fig-figwasp mutualism and a quantitative view of types of associations. Role of insects in the environment. Adaptations to terrestrial habitats. Evolution of insect diversity and role of phytophagy as an adaptive zone for increased diversity of insects. Evolution of resource harvesting organs, resilience of insect taxa and the sustenance of insect diversity- role of plants. Herbivory, pollination, predation, parasitism. Modes of insect-plant interaction, tri-trophic interactions. Evolution of herbivory, monophagy vs polyphagy. Role of plant secondary metabolites. Meaning of stress- plant stress and herbivory. Consequences of herbivory to plant fitness and response to stress. Constitutive and induced plant defenses. Host seeking behavior of parasitoids

Unit III : Biodiversity and Conservation- RET species, Ecological Indicators. Principles of Population genetics, Hardy Weinberg Law, Computation of Allelic and Phenotypic frequencies, Fitness under selection, Rates of Evolution under selection. Foraging Ecology- Optimal foraging theory, Marginal Value Theorem, and Patch departure rules, central place foraging, Mean-variance relationship and foraging by pollinators, Nutritional Ecology.

Unit IV : Reproductive ecology- Sexual selection, Mating systems, Reproductive strategies – timing, egg number, reproductive effort, sibling rivalry and parent-offspring conflict. Agro-ecological vs Natural Ecosystems – Characterisation, Pest Control as applied ecology- case studies.

Practicals

- Methods of data collection under field conditions
- Assessment of distribution parameters, Taylor's power law, Iwao's patchiness index, Index of Dispersion, etc.
- Calculation of sample sizes by different methods
- Fitting Poisson and Negative Binomial distributions and working out the data transformation methods
- Hardy-Weinberg Law, Computation of Allelic and Phenotypic Frequencies – Calculation of changes under selection, Demonstration of genetic drift
- Assessment of Patch Departure rules. Assessment of Resource size by female insects using a suitable insect model, fruit flies/ Goniozus/ Female Bruchids, etc.
- A test of reproductive effort and fitness
- Construction of Life tables and application of Leslie Matrix – population projections, Stable age distribution
- Exercises in development of Algorithms for crop modeling

Suggested Referances

Barbosa P and Letourneau DK. (Eds.). 1988. Novel Aspects of Insect-Plant Interactions. Wiley, London.

Elizabeth BA and Chapman RF. 1994. Host-Plant Selection by Phytophagous Insects. Chapman and Hall, New York.

Freeman S and Herron JC.1998. Evolutionary Analysis. Prentice Hall, New Delhi.

Gotelli NJ and Ellison AM. 2004. A Primer of Ecological Statistics. Sinauer Associates, Sunderland, MA.

Gotelli NJ. 2001. A Primer of Ecology. 3rd Ed., Sinauer Associates, Sunderland, MA, USA.
Krebs C. 1998. Ecological Methodology. 2nd Ed. Benjamin-Cummings Publ. Co., New York.
Krebs CJ. 2001 Ecology: The Experimental Analysis of Distribution and Abundance. 5th Ed. Benjamin-Cummings Publ. Co., New York.
Magurran AE. 1988. Ecological Diversity and its Measurement. Princeton University Press, Princeton.
Real LA and Brown JH. (Eds.). 1991. Foundations of Ecology: Classic Papers with Commentaries. University of Chicago Press, USA.
Southwood TRE and Henderson PA. 2000. Ecological Methods. 3rd Ed. Wiley Blackwell, London.
Strong DR, Lawton JH and Southwood R. 1984. Insects on Plants: Community Patterns and Mechanism. Harward University Press, Harward.
Wratten SD and Fry GLA. 1980. Field and Laboratory Exercises in Ecology. Arnold Publ., London.

ENT 604	Insect Behavior	1+1

Theory

Unit I : Defining Behaviour- Concept of umwelt, instinct, fixed action patterns, imprinting, complex behavior, inducted behavior, learnt behavior and motivation. History of Ethology- development of behaviorism and ethology, contribution of Darwin, Frisch, Tinbergen and Lorenz; Studying behavior- Proximate and Ultimate approaches, behavioural traits under natural selection, genetic control of behavior and behavioural polymorphism.

Unit II : Orientation- Forms of primary and secondary orientation including taxes and kinesis; Communication- primary and secondary orientation, responses to environmental stimuli, role of visual, olfactory and auditory signals in inter- and intra-specific communication, use of signals in defense, mimicry, polyphenism; evolution of signals.

Unit III : Reproductive behavior- mate finding, courtship, territoriality, parental care, parental investment, sexual selection and evolution of sex ratios; Social behavior- kin selection, parental manipulation and mutualism; Self organization and insect behavior.

Unit IV : Foraging- Role of different signals in host searching (plant and insects) and host acceptance, ovipositional behavior, pollination behavior, co-evolution of plants and insect pollinators. Behaviour in IPM- Concept of super-normal stimuli and behavioural manipulation as potential tool in pest management, use of semiochemicals, auditory stimuli and visual signals in pest management.

Practicals

- Quantitative methods in sampling behavior
- Training bees to artificial feeders
- Sensory adaptation and habituation in a fly or butterfly model, physical cues used in host selection in a phytophagous insect, chemical and odour cues in host selection in phytophagous insect (DBM or gram pod borer), colour discrimination in honey bee or butterfly model, learning and memory in bees, role of self-organization in resource tracking by honeybees
- Evaluation of different types of traps against fruit flies with respect to signals
- Use of honey bees/ Helicoverpa armigera to understand behavioural polymorphism with respect to learning and response to pheromone mixtures, respectively.

Suggested Referances

Ananthkrishnan TN. (Ed.). 1994. Functional Dynamics of Phytophagous Insects. Oxford and IBH, New Delhi.

Awasthi VB. 2001. Principles of Insect Behaviour. Scientific Publ., Jodhpur.

Bernays EA and Chapman RF. 1994. Host-Plant Selection by Phytophagous Insects.

Chapman and Hall, London. Brown LB. 1999. The Experimental Analysis of Insect Behaviour. Springer, Berlin.

Krebs JR and Davies NB. 1993. An Introduction to Behavioural Ecology. 3rd Ed. Chapman and Hall, London.

Manning A and Dawkins MS. 1992. An Introduction to Animal Behaviour. Cambridge University Press, USA.

Mathews RW and Mathews JR. 1978. Insect Behaviour. A Wiley-InterScience Publ. John Wiley and Sons, New York.

ENT 605	Bio-Inputs for Pest Management	2+1

Theory

Unit I : Scope of classical biological control and augmentative bio-control; introduction and handling of natural enemies; nutrition of entomophagous insects and their hosts, dynamics of bio-agents vis-à-vis target pest populations.

Unit II : Bio-inputs: mass production of bio-pesticides, mass culturing techniques of bioagents, insectary facilities and equipments, basic standards of insectary, viable mass-production unit, designs, precautions, good insectary practices.

Unit III : Colonization, techniques of release of natural enemies, recovery evaluation, conservation and augmentation of natural enemies, survivorship analysis and ecological manipulations, large-scale production of bio-control agents, bankable project preparation.

Unit IV : Scope of genetically engineered microbes and parasitoids in biological control, genetics of ideal traits in bio-control agents for introgressing and for progeny selections, breeding techniques of bio-control agents.

Practicals

- Mass rearing and release of some commonly occurring indigenous natural enemies
- Assessment of role of natural enemies in reducing pest populations
- Testing side effects of pesticides on natural enemies
- Effect of semio-chemicals on natural enemies, breeding of various bio-control agents, performance of efficiency analyses on target pests
- Project document preparation for establishing a viable mass-production unit/ insectary
- Observation of feeding behavior acts of predatory bugs/ beetles.

Suggested Referances

Burges HD and Hussey NW. (Eds.). 1971. Microbial Control of Insects and Mites. Academic Press, London.

Coppel HC and James WM. 1977. Biological Insect Pest Suppression. Springer Verlag, Berlin.

De Bach P. 1964. Biological Control of Insect Pests and Weeds. Chapman and Hall, London.

Dhaliwal, GS and Koul O. 2007. Biopesticides and Pest Management. Kalyani Publishers, New Delhi.

Gerson H and Smiley RL. 1990. Acarine Biocontrol Agents – An Illustrated Key and Manual. Chapman and Hall, New York.

Huffakar CB and Messenger PS. 1976. Theory and Practices of Biological Control. Academic Press, London.

ENT 606	Insect Toxicology and Residues	2+1

Theory

Unit I : Penetration and distribution of insecticides in insect systems; insecticide selectivity; factors affecting toxicity of insecticides. Modes of action of newer insecticide molecules; developments in bio-rational approaches; SPLAT; RNAi technology for pest management.

Unit II : Biochemical and physiological target sites of insecticides in insects; developments in biorationals, biopesticides and newer molecules; their modes of action and structural – activity relationships; advances in metabolism of insecticides.

Unit III : Joint action of insecticides; activation, synergism and potentiation.

Unit IV : Problems associated with pesticide use in agriculture: pesticide resistance; resistance mechanisms and resistant management strategies; pest resurgence and outbreaks; persistence and pollution; health hazards and other side effects.

Unit V : Estimation of insecticidal residues- sampling, extraction, clean-up and estimation by various methods; maximum residue limits (MRLs) and their fixation; bound and conjugated residues, effect on soil fertility; insecticide laws and standards, and good agricultural practices.

Practicals

- Residue sampling, extraction, clean-up and estimation of insecticide residues by various methods
- Calculations and interpretation of data
- Biochemical and biological techniques for detection of insecticide resistance in insects
- Preparation of EC formulation using neem oil.

Suggested Referances

Busvine JR. 1971. A Critical Review on the Techniques for Testing Insecticides. CABI, London.

Dhaliwal GS and Koul O. 2007. Biopesticides and Pest Management. Kalyani Publishers, New Delhi.

Hayes WJ and Laws ER. 1991. Handbook of Pesticide Toxicology. Academic Press, New York.

Ishaaya I and Degheele (Eds.). 1998. Insecticides with Novel Modes of Action. Narosa Publ. House, New Delhi.

Matsumura F. 1985. Toxicology of Insecticides. Plenum Press, New York.

O' Brien RD. 1974. Insecticides Action and Metabolism. Academic Press, New York.

Perry AS, Yamamoto I, Ishaaya I and Perry R. 1998. Insecticides in Agriculture and Environment. Narosa Publ. House, New Delhi.

Prakash A and Rao J. 1997. Botanical Pesticides in Agriculture. Lewis Publ., New York.

ENT 607	Plant Resistance to Insects	1+1

Theory

Unit I : Importance of plant resistance, historical perspective, desirable morphological, anatomical and biochemical adaptations of resistance; assembly of plant species – gene pool; insect sources – behaviour in relation to host plant factors.

Unit II : Physical and chemical environment conferring resistance in plants, role of trypsin inhibitors and protease inhibitors in plant resistance; biochemistry of induced resistance – signal transduction pathways, methyl jasmonate pathways, polyphenol oxidase pathways, salicylic acid pathways; effects of induced resistance; exogenous application of elicitors.

Unit III : Biotechnological approaches in host plant resistance- genetic manipulation of secondary plant substances; incorporation of resistant gene in crop varieties; markeraided selection in resistance breeding.

Unit IV : Estimation of plant resistance based on plant damage- screening and damage rating; evaluation based on insect responses; techniques and determination of categories of plant resistance; breakdown of resistance in crop varieties.

Practicals

- Understanding mechanisms of resistance for orientation, feeding, oviposition, etc., allelochemical bases of insect resistance
- Macroculturing of test insects like aphids, leaf/ plant hoppers, mites and stored grain pests
- Field screening- microplot techniques, infester row technique, spreader row technique and plant nurseries
- Determination of antixenosis index, antibiosis index, tolerance index, plant resistance index.

Suggested Referances

Panda N. 1979. Principles of Host Plant Resistance to Insects. Allenheld, Osum and Co., New York.

Rosenthal GA and Janzen DH. (Eds.). 1979. Herbivores – their Interactions with Secondary Plant Metabolites. Vol. I, II. Academic Press, New York.

Sadasivam S and Thayumanavan B. 2003. Molecular Host Plant Resistance to Pests. Marcel Dekker, New York.

Smith CM, Khan ZR and Pathak MD. 1994. Techniques for Evaluating Insect Resistance in Crop Plants. CRC Press, Boca Raton, Florida.

ENT 608	Acarology	1+1

Theory

Unit I : Comparative morphology of Acari, phylogeny of higher categories in mites, knowledge of commonly occurring orders and families of Acari in India. Diagnostic characteristics of commonly occurring species from families Tetranychidae, Tenuipalpidae, Eriophyidae, Tarsonemidae, Phytoseiidae, Bdellidae, Cunaxidae, Stigmaeidae, Pymotidae, Cheyletidae, Acaridae, Pyroglyphidae, Orthogalumnidae, Argasidae, Ixodidae, Sarcoptidae. Soil mites in India.

Unit II : Management of economical important species of mites in agriculture, veterinary and public health; storage acarology.

Unit III : Mites as vectors of plant pathogens; mode of action, structure-activity relationships of different groups of acaricides; problem of pesticide resistance in mites, resurgence of mites.

Unit IV : Predatory mites, their mass production and utilization in managing mite pests, acaropathogenic fungi- identification, isolation and utilization.

Practicals

- Identification of commonly occurring mites up to species, preparation of keys for identification
- Collection of specific groups of mites and preparing their identification keys
- Rearing phytoseiid mites and studying their role in suppression of spider mites
- Management of mite pests of crops using acaricides, phytoseiid predators, fungal pathogens, etc.

Suggested Referances

Evans GO.1992. Principles of Acarology. CABI, London.

Gerson H and Smiley RL. 1990. Acarine Bio-control Agents- An Illustrated Key and Manual.

Chapman and Hall, New York. Gupta SK. 1985. Handbook of Plant Mites of India. Zoological Survey of India, Calcutta.

Krantz GW. 1970. A Manual of Acarology. Oregon State University Book Stores, Corvallis, Oregon.

Sadana GL. 1997. False Spider Mites Infesting Crops in India. Kalyani Publ. House, New Delhi.

ENT 609	Molecular Entomology	1+1

Theory

Unit I : Introduction to molecular biology; techniques used in molecular biology.

Unit II : DNA and RNA analysis in insects- transcription and translocation mechanisms. DNA recombinant technology, identification of genes/ nucleotide sequences for characters of interest. Genetic improvement of natural enemies. Cell lines, genetic engineering in baculoviruses, Bt and entomopathogenic fungi.

Unit III : Genes of interest in entomological research- marker genes for sex identification, neuropeptides, JH esterase, St toxins and venoms, chitinase, CPTI; lectins and proteases. Transgenic plants for pest resistance and diseases.

Unit IV : Insect gene transformation; biotechnology in relation to silkworms and honey bees; introduction of lectin genes for pest suppression; DNA finger printing for taxonomy and phylogeny. Genetic improvement of inebriate tolerance of natural enemies.

Unit V : DNA-based diagnostics; insect immune systems in comparison to vertebrates; molecular basis of metamorphosis; Sf transgenic technology and implications; molecular biology of baculoviruses; insecticide resistance. Resistance management strategies in transgenic crops.

Practicals

- Isolation of DNA/ RNA;
- Purity determinations, purification of total DNA from animal tissues
- Base pair estimation; Agarose gel electrophoresis
- Quantitative enzyme profile of alimentary canal
- Restriction mapping of DNA
- Demonstration of PCR, RFLP and RAPD techniques

Suggested Referances

Bhattacharya TK, Kumar P and Sharma A. 2007. Animal Biotechnology. 1st Ed., Kalyani Publication, New Delhi.

Hagedon HH, Hilderbrand JG, Kidwell MG and Law JH. 1990. Molecular Insect Science. Plenum Press, New York.

Hoy MA. 2003. Insect Molecular Genetics: An Introduction to Principles and Applications. 2nd Ed. Academic Press, New York.
Oakeshott J and Whitten MA. 1994. Molecular Approaches to Fundamental and Applied Entomology. Springer Verlag.
Rechcigl JE and Rechcigl NA. 1998. Biological and Biotechnological Control of Insect Pests. Lewis Publ., North Carolina.
Roy U and Saxena V. 2007. A Hand Book of Genetic Engineering. 1st Ed., Kalyani Publishers, New Delhi.
Singh BD. 2008. Biotechnology (Expanding Horizons). Kalyani Publishers, New Delhi.
Singh P. 2007. Introductory to Biotechnology. 2nd Ed. Kalyani Publishers, New Delhi.

ENT 610	Integrated Pest Management	2+0

Theory

Unit I : Principles of sampling and surveillance, database management and computer programming; simulation techniques, system analysis and modeling.

Unit II : Study of case histories of national and international programmes, their implementation, adoption and criticism; global trade and risk of invasive pests; updating knowledge on insect outbreaks and their management.

Unit III : Genetic engineering and new technologies- their progress and limitations in IPM programmes, deployment of benevolent alien genes for pest management- case studies; scope and limitations of bio-intensive and ecological based IPM programmes; application of IPM to farmers' real time situation.

Unit IV : Challenges, needs and future outlook; dynamism of IPM under changing cropping systems and climate; insect pest management under protected cultivation; strategies for pesticide resistance management.

Suggested Referances

Dhaliwal GS and Arora R. 2003. Integrated Pest Management – Concepts and Approaches. Kalyani Publishers, New Delhi.
Dhaliwal GS, Singh R and Chhillar BS. 2006. Essentials of Agricultural Entomology. Kalyani Publishers, New Delhi.
Flint MC and Bosch RV. 1981. Introduction to Integrated Pest Management. Springer, Berlin.
Koul O and Cuperus GW. 2007. Ecologically Based Integrated Pest Management. CABI, London.
Koul O, Dhaliwal GS and Curperus GW. 2004. Integrated Pest Management –Potential, Constraints and Challenges. CABI, London.
Maredia KM, Dakouo D and Mota-Sanchez D. 2003. Integrated Pest Management in the Global Arena. CABI, London.
Metcalf RL and Luckman WH. 1982. Introduction to Insect Pest Management. John Wiley and Sons, New York.
Norris RF, Caswell-Chen EP and Kogan M. 2002. Concepts in Integrated Pest Management. Prentice Hall, New Delhi.
Pedigo RL. 1996. Entomology and Pest Management. Prentice Hall, New Delhi.
Subramanyam B and Hagstrum DW. 1995. Integrated Management of Insects in Stored Products. Marcel Dekker, New York.

GENETICS AND PLANT BREEDING

Sl. No.	Course No.	Course Title	Credit Hours
Major courses (Minimum 12 credits)			
1	GPB 601*	Advances in Plant Breeding Systems	3+0
2	GPB 602	Advances in Biometrical Genetics	2+1
3	GPB 603	Molecular Cytogenetics for Crop Improvement	2+0
4	GPB 604	Plant Genetics Resources, Conservation and Utilization	2+0
5	GPB 605*	Genomics in Plant Breeding	3+0
6	GPB 606	Population Genetics	2+0
7	GPB 607	Crop Evolution	3+0
8	GPB 608	Breeding Designer Crops	1+1
9	GPB 609*	IPR and Regulatory Mechanism (e-course)	1+0
10	GPB 671	Qualifying Examination	0+4
11	GPB 681	Seminar - I	0+1
12	GPB 682	Seminar - II	0+1
13	GPB 683	Seminar - III	0+1
14	GPB 691	Research	0+70

* Compulsory among major courses

GPB 601	Advances in Plant Breeding Systems	3+0

Theory

Unit I : Advances in reproductive biology of crops; Genes governing the whorls formation and various models proposed; Pollen pistil interaction: biochemical and molecular basis, environmental factors governing anthesis and bottlenecks for gene transfer.

Unit II : Plant Breeding methodologies: Classic versus modern; Over view of Pre and Post Mendelian breeding methods in self and cross pollinated crops; Molecular and transgenic breeding approaches; doubled haploid breeding, shuttle breeding, forward and reverse breeding, speed breeding, participatory plant breeding, breeding for organic situations. Advances in or Molecular basis of MABC, MARS, Precision breeding; High throughput phenotyping; GWAS and GS.

Unit III : Principles and procedures in the formation of a complex population; Genetic basis of population improvement in crop plants; Recurrent selection methods in self and cross pollinated crops and their modifications; Convergent selection, divergent selection; Recurrent selection, usefulness in hybrid breeding programs; Reciprocal recurrent selection; Selection in clonally propagated crops – Assumptions and realities.

Unit IV : Choice of molecular markers for plant breeding efficiency, fingerprinting and genetic diversity assessment, application of MAS for selection of qualitative and quantitative traits; Gene pyramiding, accelerated backcrossing, marker-based utilization of exotic germplasm, introgression libraries.

Unit V :Genetic resources: primary, secondary, tertiary and alien trans gene pool; Molecular and biochemical basis of self-incompatibility and male sterility, nucleo-cytoplasmic interactions with special reference to male sterility - genetic, biochemical and molecular bases.

Unit VI : Genetic engineering technologies to create male sterility, prospects and problems, use of self-incompatibility and sterility in plant breeding – case studies; Fertility restoration in male sterile lines and restorer diversification programs; Conversion of agronomically ideal genotypes into male sterile: Concepts and breeding strategies; Case studies - Generating new cyto-nuclear interaction system for diversification of male sterile; Stability of male sterile lines – Environmental influence on sterility, Environmentally Induced Genic Male Sterility (EGMS) – Types of EGMS; Influence on their expression, genetic studies; Photo and thermo sensitive genetic male sterilityand its use in heterosis breeding; Temperature sensitive genetic male sterility and its use in heterosis breeding; Apomixis and its use in heterosis breeding; Incongruity: Factors influencing incongruity, Methods to overcome incongruity mechanisms.

Unit VII : Breeding for climate change -Improving root systems, abiotic stress tolerance, water use efficiency, flooding and sub-mergence tolerance; Biotic stress tolerance; - plant pathogen interaction, receptor-elicitor model, guard hypothesis; Nutrient use efficiency, nitrogen fixation and assimilation, greenhouse gases and carbon sequestration; Breeding for bio-fortification.

Suggested Referances

Agarwal RL. 1996. *Fundamentals of Plant Breeding and Hybrid Seed Production*. Oxford &IBH.

Allard RW. 1966. *Principles of Plant Breeding*. John Wiley & Sons.

Briggs FN and Knowles PF. 1967. *Introduction to Plant Breeding*. Reinhold.

Fehr WR. 1987. *Principles of Cultivar Development: Theory and Technique*. Vol I. Macmillan. Hayes HK, Immer FR and Smith DC. 1955. *Methods of Plant Breeding*. McGraw-Hill.

Kang MS and Priyadarshan PM (Edit.). 2007. *Breeding Major Food Staples.* Blackwell Publishing.

Kole C. 2013. *Genomics and Breeding for Climate-Resilient Crops*. Springer. Volume 2-Target Traits.

Mandal AK, Ganguli PK and Banerji SP. 1995. *Advances in Plant Breeding*. Vol. I, II. CBS. Richards AJ. 1986. *Plant Breeding Systems*. George Allen & Unwin.

Sharma JR. 1994. *Principles and Practice of Plant Breeding*. Tata McGraw-Hill. Simmonds NW. 1979. *Principles of Crop Improvement*. Longman.

Singh BD. 1997. *Plant Breeding: Principles and Methods*. 5th Ed., Kalyani Publishers, New Delhi.

Singh P. 1996. *Essentials of Plant Breeding*. Kalyani Publishers, New Delhi. Welsh JR. 1981. *Fundamentals of Plant Genetic and Breeding*. John Wiley.

GPB 602	Advances in Biometrical Genetics	2+1

Theory

Unit I : Continuous variation-evolutionary studies; Genetic principles of continuous variation, Qualitative and quantitative techniques-differences, population types, approaches; various types of metrics, F_2, F_3 and mixed; Selection of parents, Simultaneous selection models; Use of Multiple regression analysis in selection of genotypes.

Unit II : Components of mean- Additive effect, breeding value, coefficient of gene dispersion, dominance; Simple scaling test, expectation of mean of character in various types of families in coupling and dispersed phase; Epistasis- Specification, weighted and un-weighted joint scaling test; Effect of linkage to generation mean, specification of mean to G × E interaction.

Unit III : Components of variances-advantages, variances of different generations, balance sheet of variance; estimation of parameters-weighted and unweighted, least square analysis; random mating population; experimental population-BIPs, NCD-I, II, III, Triple test cross for random mating population and inbreds; Estimates of linkage and non-allelic interactions; Combining ability analysis, Hayman's Approach.

Unit IV : G × E Interaction, stability and adaptability; Advanced models in stability analysis - Pattern analysis - Additive Main Effect and Multiplicative Interaction (AMMI) analysis and other related models; Merits and limitation of different stability analysis methods; Analysis and selection of genotypes; Methods and steps to select the best model - Biplots and mapping genotypes.

Unit V : Construction of saturated linkage maps, concept of framework map development; QTLs-different types of markers and mapping populations, linkage maps, mapping- Strategies for QTL mapping - desired populations, statistical methods; MAGIC populations, Marker Assisted Selection (MAS) - Approaches to apply MAS in Plant breeding - selection based on markers - simultaneous selection based on marker and phenotype - Factors influencing MAS; Heritability of the trait, proportion of genetic variance, linkage disequilibrium between markers and traits and selection methods; Use of advanced software packages for biometrical analysis, interpretation of analysed data, QTL based MAS approaches; Genomic Selection or Genome wide selection- Genomic selection prediction models, genomic estimated breeding value.

Practicals

- Estimation of variance of different filial generations and interpretations;
- Diallel analysis: Numerical, graphical and combining ability analysis; Triallel analysis;
- NC Designs: Triple test cross analysis;
- Generation mean analysis: ABC scaling test and Joint scaling test- Analysis and interpretation;
- Stability analysis: Eberhart and Russel model;
- AMMI model - Principal Component Analysis model - Additive and multiplicative model - Shifted multiplicative model - Analysis and selection of genotypes - Methods and steps to select the best model - Selection systems - Biplots and mapping genotypes;
- Construction of linkage maps and QTL mapping - Strategies for QTL mapping; statistical methods in QTL mapping;
- Phenotype and Marker linkage studies;
- Use of advanced software in biometrical analysis;

Suggested Referances

Bos I and Caligari P. 1995. *Selection Methods in Plant Breeding*. Chapman & Hall. Dabholkar AR.1993. *Elements of Biometrical Genetics.* Concept Publishing Co. New Delhi. Falconer DS and Mackay J. 1996. *Introduction to Quantitative Genetics* (4 Ed.). ELBS/ Longman, London.

Mather K and Jinks JL. 1985. *Biometrical Genetics* (3rd Ed.). Chapman and Hall, London.

Nandarajan N and Gunasekaran M. 2008. *Quantitative Genetics and Biometrical Techniques in Plant Breeding.* Kalyani Publishers, New Delhi.

Roy D. 2000. *Plant Breeding, Analysis and Exploitation of Variation*. Narosa Publishing House, New Delhi.

Singh P and Narayanan SS. 1993. *Biometrical Techniques in Plant Breeding*. Kalyani Publishers, New Delhi. Singh RK and Choudhary BD. 1987. *Biometrical Methods in Quantitative Genetics*. Kalyani Publishers, New Delhi.

Weir DS. 1990. *Genetic Data Analysis. Methods for Discrete Population Genetic Dat*a. Sinauer Associates.

Wricke G and Weber WE. 1986. *Quantitative Genetics and Selection in Plant Breeding*. Walter de Gruyter.

GPB 603	Molecular Cytogenetics for Crop Improvement	2+0

Theory

Unit I : Organization and structure of genome, Genome size, Organization of organellar genomes, Nuclear DNA organization, Nuclear and Cytoplasmic genome interactions and signal transduction; Inheritance and expression of organellar DNA; Variation in DNA content - C value paradox; Sequence complexity – Introns and Exons, Repetitive sequences, Role of repetitive sequence.

Unit II : Karyotyping – Chromosome banding and chromosome painting; Tracking introgressions using FISH, GISH, localization and mapping of genes/ genomic segments.

Unit III : Pre-breeding and applications of cytogenetical methods for crop improvement; Location and mapping of genes on chromosomes: deficiency method; Interchange genetic consequence, identification of chromosomes involved and gene

location; balanced lethal systems, their maintenance and utility; Multiple interchanges-use in producing inbreds, transfer of genes- linked marker methods; Duplication - production and use; Inversions and location of genes; B/ A chromosome translocations and gene location.

Unit IV : Trisomics- types, production, breeding behavior and location of genes, use of balanced tertiary trisomics in hybrid seed production; Monosomics methods of production, breeding behavior and location of genes; Intervarietal substitutions-allelic and non- allelic interactions; Telocentric method of mapping.

Unit V : Cytogenomics: Concept, tools and techniques for crop improvement; Chromosome sorting: Isolation of specific chromosome for development of molecular maps and gene location.

Unit VI : Role of polyploidy in crop evolution and breeding. Auto- and allopolyploids; Distant hybridization, barriers to interspecific and intergeneric hybridization; Behaviour of interspecific and intergeneric crosses.

Suggested Referances

Clark MS and Wall WJ. 1996. *Chromosomes: The Complex Code*. Chapman & Hall. 30 June 1996

Conger BV. (Ed.). 1981. *Cloning Agricultural Plants via in-vitro Techniques*. CRC Press. 31 January 2018

Constabel F and Vasil IK. (Eds.). 1988. *Cell Culture and Somatic Cell Genetics of Plants*. Vol.

Cell Culture and Phytochemicals in Plant Cell Cultures. Academic Press. Gupta P K. 2006. *Cytogenetics*. Rastogi Publisher

Lal R and Lal S. (Eds.). 1990. *Crop Improvement Utilizing Biotechnology*. CRC Press. Mantel SH and Smith H. 1983. *Plant Biotechnology*. Cambridge University Press.

Sen SK and Giles KL. (Eds.). 1983. *Plant Cell Culture in Crop Improvement*. Plenum Press. 13 July 2013

Yao-Shan F. 2002. *Molecular Cytogenetics: Protocols and Application.* Human Press

GPB 604	Plant Genetic Resources, Conservation and Utilization	2+0

Theory

Unit I : Concept of natural reserves and natural gene banks; *In situ* conservation of wild species in nature reserves: *in situ* conservation components, factors influencing conservation value, national plan for *in situ* conservation; *in situ* conservation of agro-biodiversity on-farm; scientific basis of *in situ* conservation on-farm, building on-farm conservation initiatives, implementation of on-farm conservation, management of *in situ* conserved genetic diversity on-farm, enhancing benefits for farmers from local crop diversity.

Unit II : *Ex situ* conservation: components, plant genetic resources conservation in gene banks, national gene banks, gene repositories, preservation of genetic materials under natural conditions, perma-frost conservation, guidelines for seed multiplication and exchange to network of active/ working collections, orthodox, recalcitrant seeds-differences in handling, clonal repositories, genetic stability under long term storage condition.

Unit III : *In-vitro* storage, maintenance of *in-vitro* culture under different conditions, *in-vitro* bank maintenance for temperate and tropical fruit crop species, spices, tubers, bulbous crops, medicinal and endangered plant species, conservation of embryos and ovules, cell/ suspension cultures, protoplast and callus cultures, pollen culture, micropropagation techniques, problems, prospects of *in-vitro* gene bank.

Unit IV : Cryopreservation- procedure for handling seeds of orthodox and recalcitrant-cryo-protectants, desiccation, rapid freezing, slow freezing, vitrification techniques, encapsulation/ dehydration techniques, national facilities, achievements, application of cryopreservation in agricultural, horticultural and forestry crops. Problems and prospects; challenges ahead.

Unit V : Concept and procedure for PGR management, germplasm characterization, evaluation and utilization; Concept of core and mini core; collections and registration of plant germplasm. Sources of genes/ traits- novel genes for quality; Descriptors; PGR access and benefit sharing; Role of CGIAR system in the germplasm exchange; Genetic enchancement/ Pre-breeding for crop improvement.

Suggested Referances

Ellis RH, Roberts EH and White Head J. 1980. *A New More Economic and Accurate Approach to Monitor the Viability of Accessions During Storage in Seed Banks*. FAO/ IBPGR Pl. Genet. Resources News 41-3-18.

Frankel OH and Hawkes JG. 1975. *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press, Cambridge.

Paroda RS and Arora RK.1991. *Plant Genetic Resource Conservation and Management*, NBPGR, New-Delhi.

Simmonds NW. 1979. *Principles of Crop Improvement*, Longman.

Westwood MN. 1986. *Operation Manual for National Clonal Germplasm Repository*. Processed Report. USDA-ARS and Oregon State Univ. Oregon, USA.

Withers LA. 1980. *Tissue Culture Storage for Genetic Conservation*. IBPGR Tech. Rep. IBPGR, Rome, Italy.

GPB 605	**Genomics in Plant Breeding**	**3+0**

Theory

Unit I : Introduction to the plant genomes: nuclear, chloroplast and mitochondrial genomes; Concept of genome size and complexity: C-value paradox, repetitive and unique DNA.

Unit II : Genome sequencing: Principles and techniques of conventional approaches and next generation sequencing including sequencing-by-synthesis/ ligation and single molecule real time (SMRT) technologies; Applications of sequence information: structural, functional and comparative genomics; Plant genome projects: Strategies for genome sequencing including shot gun and clone-by-clone method.

Unit III : Molecular maps: Use of molecular markers/ SNPs for development of genetic and physical maps; Linkage and LD-based gene mapping approaches including gene/ QTL mapping, genome wide association studies (GWAS) and association analysis; Integration of genetic and physical map for map-based cloning of economically important genes. Concept of allele mining; Diversity array technology: concepts and applications.

Unit IV : Functional genomics: concept of reverse and forward genetics; Use of activation tagging, transposon tagging, insertional mutagenesis, TILLING and ecoTILLING for crop improvement; Genome-wide and gene-specific transcriptomics approaches: serial analysis of gene expression, massively parallel signature sequencing, next generation sequencing, microarray, northern hybridization, RT-PCR, qRT-PCR and molecular beacon.

Unit V : Development and management of database; Applications of bioinformatics tools/ software in genomics for crop improvement. Basic concepts of high-throughput proteomics, metabolomics and phenomics.

Unit VI : Recent transgene free genome editing tools such as CRISPR-Cas9 system, TALENS and ZFNs for crop improvement. Cisgenesis and Intragenesis tools as twin

sisters for Crop Improvement; Genomics-based plant breeding: Genome-Wide Genetic Diversity Studies, Identification of molecular markers linked to single Genes and QTL, Marker Assisted Selection (Marker Assisted Backcross Selection, Association mapping, Breeding by Design, Genome selection).

Suggested Referances

Alonso JM, Stepanova AN. 2015. *Plant Functional Genomics: Methods and Protocols*. Springer. Chopra VL, Sharma RP, Bhat SR and Prasanna BM. 2007. *Search for New Genes*. Academic Foundation, New Delhi.

Hackett PB, Fuchs JA and Messing JW. 1988. *An Introduction to Recombinant DNA Technology— Basic Experiments in Gene and Manipulation*. 2nd Ed. Benjamin Publication Co.

Primose SB and Twyman RM. 2006. *Principles of Gene Manipulation and Genomics*. 7th Ed. Wiley-Blackwell Publishing.

Sambrook J and Russel D. 2001. *Molecular Cloning - a Laboratory Manual*. 3rd Ed. Cold Spring Harbor Laboratory Press.

Singh BD. 2005. *Biotechnology: Expanding Horizons*. Kalyani Publishers, New Delhi. Somers DJ, Langridge P, Gustafson JP. 2009. *Plant Genomics: Methods and Protocols*. Springer.

GPB 606	Population Genetics	2+0

Theory

Unit I : Population: Properties of population, Mendelian population; Genetic constitution of a population through time, space, age structure, etc.; Frequencies of genes and genotypes; Causes of change: population size, differences in fertility and viability, migration and mutation.

Unit II : Hardy-Weinberg equilibrium, Hardy-Weinberg law, Proof and applications of the Hardy-Weinberg law, Test of Hardy-Weinberg equilibrium; Mating frequencies: Non-dominance, Codominance, Snyder's ratio, importance and its effect over random mating in succeeding generations.

Unit III : Equilibrium with respect to multiple alleles, More than one locus, Sex linked genes; Use of gene and genotypic frequencies evaluation in field population level; Interpretations - Changes of gene frequency, Migration, Mutation, Recurrent and non-recurrent Selection; Balance between selection and mutation; Selection favoring heterozygotes; Overdominance for fitness.

Unit IV : Mating systems, Random mating population, Nonrandom mating: selfing – inbreeding coefficient, panmictic index, sibmating, Assortative mating and disassortative mating; Pedigree populations and close inbreeding, Estimation of linkage disequilibrium, Correlation between relatives and estimation of F; Effect of inbreeding and sibbing in cross pollinated crops; Gene substitution and average effects; Breeding value- Genetic drift; Genetic slippage, Co-adapted gene complexes; Homoeostasis-Adaptive organization of gene pools; Polymorphism- Balanced and Non-balanced polymorphism, heterozygous advantage- Survival of recessive and deleterious alleles in populations.

Suggested Referances

Chawla V and Yadava RK. 2006. *Principles of Population Genetics – A Practical Manual*. Dept. of Genetics, CCS HAU Hisar.

Falconer DS and Mackay J. 1996. *Introduction to Quantitative Genetics*.

Longman. Jain JP, Jain J and Parbhakaran VT. 1992. *Genetics of Populations*. South Asia Books. Li CC. 1955. *Population Genetics*. The Univ. of Chicago Press.

Mather K and Jinks JL. 1982. *Biometrical Genetics*. Chapman & Hall.

Sorrens D and Doniel G. 2007. *Methods in Quantitative Genetics*. Series: *Statistics for Biology and Health*. Likelihood.
Tomar SS. 1992. *Text Book of Population Genetics*. Universal Publication.

GPB 607	Crop Evolution	3+0

Theory

Unit I : Origin and evolution of species; Centres of diversity/ origin, diffused centres; Time and place of domestication; Patterns of evolution and domestication-examples and Case studies; Domestication and uniformity – Characteristics of early domestication and changes – Concept of gene pools and crop evolution; Selection and Genetic drift – Consequences.

Unit II : Speciation and domestication–The process of speciation; Reproductive isolation barriers; Genetic differentiation during speciation; Hybridization - speciation and extinction; Exploitation of natural variation: Early attempts to increase variation, Distant hybridization and introgression, Inter-specific, inter-generic hybridization, scope and limitations, techniques to overcome the limitations; Gene transfer into cultivated species, tools and techniques; Validation of transferred genes and their expression; Controlled introgressions.

Unit III : Processes in crop evolution and stabilization of polyploids, cytogenetic and genetic stabilization; Genome organization – Transgenesis in crop evolution, Multifactorial genome, Intragenomic interaction, Intergenomic interaction, Genome introgression; Methods to study crop evolution - Contemporary Methods, Based on morphological features, Cytogenetic analysis, Allozyme variations and crop evolution, DNA markers, genome analysis and comparative genomics.

Unit IV : Evolutionary significance of polyploidy, evolution of crop plants through ploidy manipulations; Polyploids: methods, use of autopolyploids; haploidy and DH-method of production and use, allopolyploids; synthesis of new crops; Case studies – vegetables, Plantation crops, Tuber crops, Medicinal Plants.

Suggested Referances

Hancock JF. 2004. *Plant Evolution and the Origin of Crop Species*. 2nd Ed. CABI.
Ladizinsky G. 1999. *Evolution and Domestication.* Springer.
Miller AJ. 2007. *Crop Plants: Evolution*. John Wiley & Sons.
Smartt J and Simmonds NW. 1995. *Evolution of Crop Plants*. Blackwell.

GPB 608	Breeding Designer Crops	1+1

Theory

Unit I : Breeding of crop ideotypes; Genetic manipulations through recombination breeding, genomics and transgenics for physiological efficiency, nutritional enhancement, special compounds-proteins, vaccines, gums, starch and fats.

Unit II : Physiological efficiency as a concept, parametric and whole plant physiology in integrated mode; Physiological mechanism of improvement in nutrient use efficiency, water use efficiency, osmotic adjustment, photosynthetic efficiency, stay green trait and its significance in crop improvement; Breeding for special traits, *viz*., oil, protein, vitamins, amino acids, *etc*.; Ecospecific ideotypes, Ideotypes for high and low moisture conditions, low and high input conditions, conversion mechanism of C_3 to C_4 plants; climate smart crop varieties; Determination of genetics of above mentioned traits.

Unit III : Improvement in yield potential under sub-optimal conditions by manipulating source and sink, canopy architecture, plant-water relationships, effect of suboptimal

conditions on cardinal plant growth and development processes, enhancing input use efficiency through genetic manipulations.

Unit IV : Concept of biopharming and development of varieties producing targeted compounds, nutraceuticals and industrial products; Success stories in vaccines, modified sugars, gums and starch through biopharming.

Unit V : Biosafety management, segregation and isolation requirements in designer crop production and post-harvest management.

Practicals

- Demonstration of plant responses to stresses through recent techniques;
- Water use efficiency, transpiration efficiency, screening techniques under stress conditions such as electrolyte leakage, TTC, chlorophyll fluorescence, canopy temperature depression, stomatal conductance, chlorophyll estimation, heat/ drought/ salt shock proteins.
- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

Suggested Referances

Balint A. 1984. *Physiological Genetics of Agricultural Crops*. AK Ademiaikiado. Hay RK. 2006. *Physiology of Crop Yield*. 2nd Ed. Blackwell.

Pessarakli M. 1995. *Handbook of Plant and Crop Physiology*. Marcel Dekker. Taiz L and Zeiger E. 2006. *Plant Physiology*. 4th Ed. Sinauer Associates.

GPB 609	IPR and Regulatory Mechanism (e-course)	1+0

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement

Suggested Referances

Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.

Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.

Intellectual Property Rights: Key to New Wealth Generation. 2001. NRDC & Aesthetic Technologies.

Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. *Technology Generation and IPR Issues.* Academic Foundation**.**

PLANT PATHOLOGY

Sl. No.	Course No.	Course Title	Credit Hours
Major courses (Minimum 12 credits)			
1	PAT 601	Advances in Mycology	2+1
2	PAT 602	Advances in Virology	2+1
3	PAT 603	Advances in Plant Pathogenic Prokaryotes	2+1
4	PAT 604*	Molecular Basis of Host-pathogen Interaction	2+1
5	PAT 605	Principles and Procedures of Certification	1+0
6	PAT 606	Plant Biosecurity and Biosafety	2+0
7	PAT 607	Advances in Plant Nematology	2+1
8	PAT 608	Advances in Seed Pathology	1+1
9	PAT 609	Advances in Epidemiology, Forecasting and Loss Assessment of Plant Diseases	1+1
10	PAT 610	Advances in Biological Management of Plant Diseases	1+1
11	PAT 611	Advances in Disease Resistance in Plants	1+1
12	PAT 671	Qualifying Examination	0+4
13	PAT 681	Seminar-I	0+1
14	PAT 682	Seminar-II	0+1
15	PAT 683	Seminar-III	0+1
16	PAT 691	Research	0+70

*Compulsory among major courses

PAT 601	Advances in Mycology	2+1

Theory

UNIT I : General introduction, historical development and advances in mycology. Recent taxonomic criteria, morphological criteria for classification. Serological, chemical (chemotaxonomy), molecular and numerical (computer-based assessment) taxonomy. Interaction between groups: Phylogeny, Micro conidiation, conidiogenesis and sporulating structures of fungi imperfect.

UNIT II : Population biology, pathogenic variability/ vegetative compatibility. Heterokaryosis and parasexual cycle. Sex hormones in fungi. Pleomorphism and speciation in fungi. Mechanism of nuclear inheritance. Mechanism of extra-nuclear inheritance. Biodegradation.

UNIT III : Ultra structures and chemical constituents of fungal cells, functions of cell organelles. Mitosis, meiosis, gene action and regulation. Effects of fungal interaction with host plants and other microorganisms; parasitism, symbiosis and commensalism.

UNIT IV : Genetic Improvement of Fungal strains. Fungal biotechnology. Fungi mediated synthesis of nano particles - characterization process and application. Mycotoxin problems and its management.

Practicals

Isolation, purification and identification of cultures, spores and mating type determination. Study of conidiogenesis-Phialides, porospores, arthospores. Study of fruiting bodies in Ascomycotina. Identification of fungi up to species level. Study of hyphal anastomosis. Morphology of representative plant pathogenic genera form different groups of fungi. Molecular characterization of fungi.

Suggested Referances:

Alexopoulos CJ, Mims CW & Blackwell M. 1996. Introductory Mycology. John Wiley & Sons, New York.

Dube HC. 2005. An Introduction to Fungi. 3rd Ed. Vikas Publ. House, New Delhi.

Kirk PM, Cannon PF, David JC & Stalpers JA. (Eds.). 2001. Ainsworth and Bisby's Dictionary of Fungi. 9th Ed., CABI, Wallington.

Maheshwari R 2016. Fungi: Experimental Methods in Biology 2nd edn. CRC Press, US.

Ulloa M & Hanlin RT. 2000. Illustrated Dictionary of Mycology. APS, St. Paul, Minnesota.

Webster J & Weber R. 2007. Introduction to Fungi. Cambridge Univ. Press, Cambridge

PAT 602	Advances in Virology	2+1

Theory

UNIT I : Origin, evolution and interrelationship with animal viruses. Virus morphology, structure, architecture, replication (overview of host and viral components required), assembly and virus specific cytological effects in infected plant cells. Mechanisms leading to the evolution of new viruses/strains: mutation, recombination, pseudo-recombination, component re-assortment etc.

UNIT II : Major vector groups of plant viruses and their taxonomy, virus-vector relationship, molecular mechanisms of virus transmission by vectors. Terminologies used in immunology and serology. Classification, structure and functions of various domains of Immunoglobulins. Production of Polyclonal and monoclonal antibodies for detection of viruses. Immuno/serological assays (Slide agglutination tests, Test tube precipitation

test, Double agar diffusion test, ELISA (DAC, DAS, TAS), Dot Immuno Binding Assay and lateral flow assay and

UNIT III : Nucleic acid-based assays for detection of plant viruses- Polymerase Chain Reaction, reverse transcriptase PCR, multiplex PCR, Nested PCR, Real time/q PCR) and non PCR based: LAMP, RPA, RCA, NGS, microarray, Fluorescent *in situ* hybridization (FISH), dot blot hybridization. Plant virus genome organization (General properties of plant viral genome- information content, coding and non-coding regions), replication, transcription and translational strategies of pararetroviruses, geminiviruses, tobamo, poty-, bromo, cucumo, ilar, tospoviruses, satellite viruses and satellite RNA.

UNIT IV : Gene expression, regulation and viral promoters. Genetic engineering with plant viruses, viral suppressors, RNAi dynamics and resistant genes. Virus potential as vectors, genetically engineered resistance, transgenic plants. Techniques and application of tissue culture for production of virus free planting materials. Phylogenetic grouping system based on partial/complete sequences of virus genomes and using of next generation sequencing technology in plant virus discovery.

Practicals

Purification of viruses, SDS-PAGE for molecular weight determination, production of polyclonal antiserum, purification of IgG and conjugate preparation. Acquaintance with different serological techniques (i) DAC- ELISA (ii) DAS-ELISA (iii) DIBA (iv) Western blotting (v) Lateral flow assay. Nucleic acid isolation, DOT-blot, southern hybridization, probe preparation and autoradiography. PCR application and viral genome cloning of PCR products, plasmid purification, restriction enzyme digestion, sequencing, annotation of genes, analysis of viral sequences. Bioinformatics analysis tools for virology (ORF finder, Gene ontology, BLAST, Clustal X/W, RDP and Phylogeny programs etc).

Suggested Referances

Calum Rae Wilson,2014, Applied Plant Virology, - CABI

Davies 1997. *Molecular Plant Virology: Replication and Gene Expression*. CRC Press, Florida.

Fauquet et al. 2005. Vius Taxonomy. VIII Report of ICTV. Academic Press, New York.

Gibbs A & Harrison B. 1976. Plant Virology - The Principles. Edward Arnold, London.

Jones P, Jones PG & Sutton JM. 1997. Plant Molecular Biology: Essential Techniques. John Wiley & Sons, New York.

Khan J. A. & Dijkstra. 2002. Plant Viruses as Molecular Pathogens. Howarth Press, New York.

Maramorosch K, Murphy FA & Shatkin AJ. 1996. Advances in Virus Research. Vol. 46. Academic Press, New York.

Pirone T. P. & Shaw JG. 1990. Viral Genes and Plant Pathogenesis. Springer Verlag, New York.

Roger Hull 2002. Mathew's Plant Virology (4th Ed.). Academic Press, New York.Roger Hull- 2009. Comparative Plant Virology, 2nd Edition, Publisher. Elsevier Thresh J. M. 2006. Advances in Virus Research Academic Press, New York.

PAT 603	Advances in Plant Pathogenic Prokaryotes	2+1

Theory

UNIT I : Prokaryotic cell: Molecular basis for origin and evolution of prokaryotic life, RNA world, prokaryotic cytoskeletal proteins. Flagella structure, assembly and regulation. Structure and composition (bacteria) cell wall/envelop, Types of secretion systems (TI to TIV) and their molecular interaction, fimbriae and pili (Type IV pili), Bacterial chromosomes and plasmids, other cell organelles. Growth, nutrition and

metabolism in prokaryotes (Embden Meyerhof pathway, Phosphoketolase Pathway and Entner Doudoroff Pathway).

UNIT II : Current trends in taxonomy and identification of phytopathogenic prokarya: International code of nomenclature, Polyphasic approach, New/ special detection methods for identification of bacterial plant pathogens. Taxonomic ranks hierarchy; Identification, Advances in classification and Nomenclature.

UNIT III : Bacterial genetics: General mechanism of variability (mutation), specialized mechanisms of variability. Transposable genetic elements in bacteria-integron and prophages, Mechanism of gene transfer. Pathogenicity islands, horizontal gene transfer, Bacterial Pan-Genome.

UNIT IV : Bacteriophages: Composition, structure and infection. Classification and use of phages in plant pathology/bacteriology. Host pathogen interactions: Molecular mechanism of pathogenesis: Pathogenicity factors of soft rot, necrosis, wilt, canker etc. Immunization, induced resistance/ Systemic Acquired Resistance, Quorum sensing. Bacterial pathogenicity and virulence: Molecular mechanism of virulence and pathogenesis, bacterial secretion systems, pathogenicity of bacterial enzymes that degrade the cell walls, Role of hrp/hrc genes and TALE effectors. Synthesis and regulation of EPSs.

UNIT V : Beneficial Prokaryotes-Endophytes, PGPR, Phylloplane bacteria and their role in disease management. Endosymbionts for host defence. Advances in management of diseases caused by prokaryotes: genetic engineering, RNA silencing; CRISPR cas9.

Practicals

Pathogenic studies and race identification, plasmid profiling of bacteria, fatty acid profiling of bacteria, RFLP profiling of bacteria and variability status, Endospore, Flagella staining, Test for secondary metabolite production, cyanides, EPS, siderophore, specific detection of phytopathogenic bacteria using species/pathovar specific primers. Basic techniques in diagnostic kit development, Molecular tools to identify phytoendosymbionts. Important and emerging diseases and their management strategies.

Suggested Referances

Dale JW & Simon P. 2004. *Molecular Genetics of Bacteria.* John Wiley & Sons, New York.

Garrity GM, Krieg NR & Brenner DJ. 2006. *Bergey's Manual of Systematic Bacteriology: The Proteobacteria.* Vol. II. Springer Verlag, New York.

Gnanamanickam SS. 2006. *Plant-Associated Bacteria*. Springer Verlag, New York.

Mount MS & Lacy GH. 1982. *Plant Pathogenic Prokaryotes*. Vols. I, II. Academic Press, New York.

Sigee DC. 1993. *Bacterial Plant Pathology: Cell and Molecular Aspects*. Cambridge Univ. Press, Cambridge.

Starr MP. 1992. *The Prokaryotes*. Vols. I – IV. Springer Verlag, New York.

PAT 604	Molecular Basis of Host-Pathogen Interaction	2+1

Theory

UNIT I : History of host plant resistance and it's importance to Agriculture. Importance and role of biotechnological tools in plant pathology. Basic concepts and principles to study host pathogen relationship. Molecular genetics, imaging and analytical chemistry tools for studying plant-microbes interactions.

UNIT II : Different forms of plant-microbe interactions and nature of signals/effectors underpinning these interactions. Plant innate immunity: PAMP/DAMP. Molecular basis of host-pathogen interaction-fungi, bacteria, viruses and nematodes; recognition system, signal transduction.

UNIT III : Induction of defence responses- HR, programmed cell death, reactive oxygen species, systemic acquired resistance, induced systemic resistance, pathogenesis related proteins, phytoalexins and virus induced gene silencing. Molecular basis of gene-for-gene hypothesis; R-gene expression and transcription profiling, mapping and cloning of resistance genes and marker-aided selection, pyramiding of R genes. Gene for gene systems: Background, genetics, phenotypes, molecular mechanisms, races, breakdown of resistance (boom-and-bust cycles), Coevolution-arms race and trench warfare models, Metapopulations, cost of resistance, cost of unnecessary virulence, GFG in agricultural crops vs. natural populations, Durability of resistance, erosion of quantitative resistance.

UNIT IV : Pathogen population genetics and durability, viruses vs cellular pathogens. Gene deployment, cultivar mixtures. Disease emergence, host specialization. Circadian clock genes in relation to innate immunity. Biotechnology and disease management; development of disease resistance plants using genetic engineering approaches, different methods of gene transfer, biosafety issues related to GM crops.

Practicals

Protein, DNA and RNA isolation, plasmid extraction, PCR analysis, DNA and Protein electrophoresis, bacterial transformation. Gene mapping and marker assisted selection. Development and use of molecular markers in identification and characterization of resistance to plant pathogens and their management.

Suggested Referances

Chet I. 1993. *Biotechnology in Plant Disease Control.* John Wiley & Sons, New York.

Gurr SJ, McPohersen MJ & Bowlos DJ. (Eds.). 1992.*Molecular Plant Pathology - A Practical Approach.* Vols. I & II, Oxford Univ. Press, Oxford.

Mathew JD. 2003. *Molecular Plant Pathology*. Bios Scientific Publ., UK.

Ronald PC. 2007. *Plant-Pathogen Interactions: Methods in Molecular Biology*. Humana Press, New Jersey.

Stacey G & Keen TN. (Eds.). 1996. *Plant Microbe Interactions*. Vols. I-III. Chapman & Hall, New York; Vol. IV. APS Press, St. Paul, Minnesota.

PAT 605	Principle and Procedures of Certificate	1+0

Theory

UNIT I : Introduction to certification. International scenario of certification and role of ISTA, EPPO, OECD etc. in certification and quality control. Case studies of certification systems of USA and Europe. National Regulatory mechanism and certification system including seed certification, minimum seed certification standards. National status of seed health in seed certification. Methods for testing genetic identity, physical purity, germination percentage, seed health etc. Fixing tolerance limits for diseases and insect pests in certification and quality control programmes.

UNIT II : Methods used in certification of seeds, vegetative propagules and *in vitro* cultures. Accreditation of seed testing laboratories. Role of seed/planting material health certification in national and international trade.

Suggested References:

Association of Official Seed Certifying Agencies. http://www.aosca.org/index.htm. Hutchins D & Reeves JE. (Eds.). 1997.

Seed Health Testing: Progress Towards the 21st Century. CABI, UK. ISHI-veg Manual of Seed Health Testing Methods. http://www.worldseed.org/enus/international_seed/ishi_vegetable.html

ISHI-F Manual of Seed Health Testing Methods. http://www.worldseed.org/en-us/international _seed/ ishi_f.html

ISTA Seed Health Testing Methods. http://www.seedtest.org/en/content--1--1132--241.html Tunwar NS & Singh SV. 1988. Indian Minimum Seed Certification Standards. Central Seed

Certification Board, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi. US National Seed Health System. http://www.seedhealth.org

PAT 606	Plant Biosecurity and Biosafety	2+0

Theory

UNIT I : Introduction and History of biosecurity and its importance. Concept and Components of biosecurity. Quarantine, Invasive Alien Species, Biowarfare, Emerging / resurgence of pests and diseases.

UNIT II : National Regulatory Mechanism and International Agreements/Conventions viz., Agreement on Application of Sanitary and Phytosanitary (SPS) Measures. World Trade Organization (WTO), Convention on Biological Diversity (CBD), International Standards for Phytosanitary Measures, pest risk analysis, risk assessment models, pest information system, early warning and forecasting system, use of Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity.

UNIT III : Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, Issues related to release of genetically modified crops. Emerging/resurgence of pests and diseases in the changing scenario of climatic conditions. Issues related to release of genetically modified crops.

Suggested References

FAO Biosecurity Toolkit 2008. www.fao.org/docrep/010/a1140e/a1140e00.htm Laboratory Biosecurity Guidance.

http://www.who.int/csr/resources/publications/biosafety/WHO_CD S_EPR_2006.pdf

Grotto Andrew J & Jonathan B Tucker. 2006. Biosecurity: A Comprehensive Action Plan. http://www.americanprogress.org/kf/biosecurity_a_comprehensive_action_plan.pdf

Randhawa GJ, Khetarpal RK, Tyagi RK &Dhillon. BS (Eds.). 2001. Transgenic Crops and Biosafety Concerns. NBPGR, New Delhi.

Khetarpal RK &Kavita Gupta 2006. Plant Biosecurity in India - Status and Strategy. Asian Biotechnology and Development Review 9(2): 3963.

Biosecurity for Agriculture and Food Production. http://www.fao.org/biosecurity/ CFIA.http://www.inspection.gc.ca/english/anima/heasan/fad/biosecure.sht ml

PAT 607	Advances in Plant Nematology	2+1

Theory

UNIT I : Nematode ultra structure; current theories on non conventional approaches in nematode identification; evolution of parasitism

UNIT II : Genetic basis of plant resistance to nematodes and identification of resistance genes against major plant nematodes; applications of biotechnological methods in the development of resistant cultivars; incorporation of resistance by conventional and transgenic approaches; influence of microorganisms on plant nematode interaction.

UNIT III : Isolation, identification, host-specificity, mode of action culturing and field application of promising bio-control agents; their mass culturing, formulation, quality control, biosafety and registration, INM modules, management options in organic and

precision farming, application of GIS and GPS technologies for surveillance and management.

UNIT IV : Host recognition plant nematode interaction: survival strategies in nematodes. Novel approaches for nematode management including genetic engineering.

Practicals : Identification of species/ races of root- knot, cyst and other nematodes using PAGE, Histopathology using microtomy, screening techniques for assessment of resistance, Greenhouse experimentation the efficacy of fungal and bacterial biocontrol agents including PGPR, Isolation of nematode proteins and DNA, PCR- amplification of DNA for nematode identification.

Suggested Referances

Perry RN & Moens M. 2006. Plant Nematology. CABI, London.

Garrity GM, Krieg NR & Brenner DJ. 2006. Bergey's Manual of Systematic Bacteriology: The Proteobacteria. Vol. II. Springer Verlag, New York.

Southey JF. 1986. Laboratory Methods for Work with Plant and Soil Nematodes. HMSO, London.

Luc M, Sikora RA and Bridge J. 2005. Plant Parasitic Nematodes in Subtropical and Tropical Agriculture. CABI, Wallingford.

Khan MW. 1993. Nemic Interactions. Chapman and Hall, New York.

Chen Z X, Chen SY and Dickson DW. 2004. Nematology: Advances and Perspectives. Vol.II: Nematode Management and Utilization. CABI, Wallingford.

Chen ZX, Chen SY & Dickson DW. 2004. Nematology: Advances and perspectives. Vol. I. Nematode Morphology, physiology and Ecology. CABI, Wallingford.

Geraert E. 2006. Nematology Monographs and Perspectives. Vol. IV.

Brill.Fenoll C, Grundler FMW & Ohl SA. 1997. Cellular and Molecular aspects of Plant-Nematode Relationships. Kluwer Academic Press, Dordrecht.

Chen ZX, Chen SY and Dickson DW. 2004. Nematology: Advances and Perspectives Vol. II. Nematode Management and Utilization. CABI, Wallingford.

Poinar GO Jr and Jansson H-B. 1988. Diseases of nematodes. Vols. I, II. CRC Press, Boca Raton, Florida.

www.fao.org/docrep/010/a1140e/a1140e00.htm

http.//www.who.int/csr/resources/publications/biosafety/WHO_CD S_EPR_2006.pdf

PAT 608	Advances in Seed Pathology	1+1

Theory

UNIT I : Economic importance of seed pathology in seed industry, plant quarantine, SPS under WTO and Pest Risk Analysis (PRA) Advances in Morphology and anatomy of typical monocotyledonous and dicotyledonous infected seeds.

UNIT II : Advances in the cause and establishment of disease in seed and seedling. Advances in mechanism of seed transmission in relation to seed infection, seed to plant transmission of pathogens.

UNIT III : Seed certification and tolerance limits, types of losses caused by seed-borne diseases in true and vegetatively propagated seeds, evolutionary adaptations of crop plants to defend seed invasion by seed-borne pathogens. Advances in influence of epidemiological factors influencing the transmission of seed-borne diseases, computer model based forecasting of epidemics through seed-borne infection.

UNIT IV : Advances in production of toxic metabolites affecting seed quality and its impact on human, animal and plant health, management of seed-borne pathogen/diseases and procedure for healthy seed production, seed health testing, methods for detecting microorganism.

Practicals

Advanced techniques in the detection and identification of seed- borne fungi, bacteria and viruses. Relationship between seed-borne infection and expression of the disease in the field/ orchards.

Suggested References

Agarwal V.K., 2006, Seed Health, IBDCO Publication, New Delhi.

Agarwal VK & JB Sinclair. 1993. Principles of Seed Pathology. Vols. I & II, CBS Publ., New Delhi.

Hutchisnt s JD & Reeves JE. (Eds.). 1997. Seed Health Testing: Progress Towards the 21 Century. CABI, Wallington.

Paul Neergaard. 1988. Seed Pathology. MacMillan, London.

Suryanarayana D. 1978. Seed Pathology. Vikash Publ., New Delhi.

PAT 609	Advances in Epidemiology Forecasting and Loss Assessment of Plant Diseases	1+1

Theory

UNIT I : Advances in concept of plant disease epidemic, pathometry and crop growth stages, epidemic growth and analysis, systems approach in epidemiology

UNIT II : Advances in common and natural logarithms, function fitting area under disease progress curve and correction factors, inoculum dynamics, population biology of pathogens, temporal spatial variability in plant pathogens, modeling of epidemics.

UNIT III : Advances in conducting survey, surveillance and vigilance, Remote sensing, Image analysis, crop loss assessment and models.

UNIT IV : Advanced concepts in understanding principles and pre-requisites of forecasting, systems and factors affecting various components of forecasting, some early forecasting, procedures based on weather and inoculum potential, modeling disease growth and disease prediction.

Practicals

Advanced techniques in measuring diseases, spore dispersal and trapping, weather recording, survey, multiplication of inoculum, inoculation techniques, computerized data analysis, function fitting, model preparation and validation

Suggested References

Campbell CL & Madden LV. 1990. Introduction to Plant Disease Epidemiology. John Wiley & Sons. New York

Cowling EB & Horsefall JG. 1978. Plant Disease. Vol. II. Academic Press, New York.

Laurence VM, GarethH& Frame Van den Bosch (Eds.). The Study of Plant Disease Epidemics. APS, St. Paul, Minnesota.

Nagarajan S & Murlidharan K. 1995. Dynamics of Plant Diseases. Allied Publ., New Delhi.

Thresh JM. 2006. Plant Virus Epidemiology. Advances in Virus Research 67, Academic Press, New York.

Van der Plank JE. 1963. Plant Diseases Epidemics and Control. Academic Press, New York.

Zadoks JC & Schein RD. 1979. Epidemiology and Plant Disease Management. Oxford Univ. Press, London.

PAT 610	Advances in Biological Management of Plant Diseases	1+1

Theory

UNIT I : Modern concepts of biological control, definitions, importance, principles of plant disease management with bioagents, history of biological control, merits and demerits of biological management.

UNIT II : Advances in mechanisms involved in biological interactions, competition, mycoparasitism, exploitation for hypovirulence, rhizosphere colonization, competitive saprophytic ability, antibiosis, induced resistance, mycorrhizal associations, operational mechanisms and its relevance in biological management.

UNIT III : Advances in understanding factors governing biological management, role of physical environment, agroecosystem, operational mechanisms and cultural practices in biological management of pathogens, pathogens and antagonists and their relationship, biocontrol agents, comparative approaches to biological control of plant pathogens by resident and introduced antagonists, control of soil-borne and foliar diseases. Compatibility among different bioagents as well as with other fungistatic compounds.

UNIT IV : Modern concepts and advances in commercial production of antagonists, their delivery systems, application and monitoring, biological control in IDM, IPM and organic farming system, biopesticides available in market. Quality control system of biocontrol agents.

Practicals

Advanced methodology for Isolation, characterization and maintenance of antagonists, methods of study of antagonism and antibiosis, application of antagonists against pathogen in vitro and in vivo conditions. Study of cfu/g.

Suggested References

Campbell R. 1989. Biological Control of Microbial Plant Pathogens. Cambridge Univ. Press, Cambridge.

Cook RJ & Baker KF. 1983. Nature and Practice of Biological Control of Plant Pathogens. APS, St. Paul, Mennisota.

Fokkemma MJ. 1986. Microbiology of the Phyllosphere. Cambridge Univ. Press, Cambridge.

Gnanamanickam SS (Eds). 2002. Biological Control of Crop Diseases. CRC Press, Florida.

Heikki MT & Hokkanen James M (Eds.). 1996. Biological Control - Benefits and Risks. Cambridge Univ. Press, Cambridge.

Mukerji KG, Tewari JP, Arora DK & Saxena G. 1992. Recent Developments in Biocontrol of Plant Diseases. Aditya Books, New Delhi.

PAT 611	Advances in Disease Resistance in Plants	1+1

Theory

UNIT I : Advances in dynamics of pathogenicity, process of infection, invasion colonization, variability in plant pathogens, sources of resistance, Modern concepts and terminologies in disease resistance.

UNIT II : Disease escapes, disease tolerance, disease resistance, types of resistance, identification of physiological races of pathogens, disease progression in relation to resistance, stabilizing selection pressure in plant pathogens.

UNIT III : Host defence system, morphological and anatomical resistance, preformed chemicals in host defence, post infectional chemicals in host defence, phytoalexins, hypersensitivity and its mechanisms.

UNIT IV

Gene-for-gene concept, protein-for-protein and immunization basis, management of resistance genes. Strategies for gene deployment.

Practicals

Detection of plant morphological structures associated with resistance, Detection and estimation of preformed and post inflectional defence mechanism associated with major plant diseases.

Suggested References

Deverall BJ. 1977. Defence Mechanisms in Plants. Cambridge Univ. Press, Cambridge, New York.

Mills Dallice et al.1996. Molecular Aspects of Pathogenicity and Resistance: Requirement for Signal Transduction. APS, St Paul, Minnesota.

Parker J. 2008. Molecular Aspects of Plant Diseases Resistance. Blackwell Publ.

Robinson RA. 1976. Plant Pathosystems. Springer Verlag, New York.

Singh BD.2005. Plant Breeding – Principles and Methods. 7 Ludhiana Ed. Kalyani Publ.,

Van der Plank JE. 1975. Principles of Plant Infection. Academic Press, New York.

Van der Plank JE. 1978. Genetic and Molecular Basis of Plant Pathogenesis. Springer Verlag. New York.

Van der Plank JE. 1982. Host Pathogen Interactions in Plant Disease. Academic Press, New York.

Van der Plank JE. 1984. Disease Resistance in Plants. Academic Press, New York.

MOLECULAR BIOLOGY AND BIOTECHNOLOGY

Sl. No.	Course No.	Course Title	Credit Hours
Major courses (Minimum 12 credits)			
1	MBB 601*	Plant Molecular Biology	3+0
2	MBB 602*	Plant Genome Engineering	3+0
3	MBB 603	Plant Omics and Molecular Breeding	3+0
4	MBB 604	Commercial Plant Tissue Culture	2+0
5	MBB 605	Plant Microbe Interaction	2+0
6	MBB 606	RNA Biology	1+0
7	MBB 607	Plant Hormones and Signaling	2+0
8	MBB 608	Computational and Statistical Tools in Biotechnology	1+1
9	MBB 671	Qualifying Examination	0+4
10	MBB 681	Seminar-I	0+1
11	MBB 682	Seminar-II	0+1
12	MBB 683	Seminar-III	0+1
13	MBB 691	Research	0+70

* Compulsory among major courses

MBB 601	Plant Molecular Biology	3+0

Theory

Unit I (10 Lectures) : Model Systems in Plant Biology (Arabidopsis, Tomato, Tobacco Mustard *etc*.) Forward and Reverse Genetic Approaches. Organization expression and interaction of Nuclear, Mitochondrial and Chloroplast Genomes. Cytoplasmic male sterility.

Unit II (12 Lectures) : Transcriptional and Post-transcriptional Regulation of Gene expression, Isolation of promoters and other regulatory elements, RNA interference, Transcriptional Gene Silencing, Transcript and Protein Analysis.

Unit III (12 Lectures) : Plant Developmental Processes, ABC Model of Floral Development, Role of hormones (Ethylene, Cytokinin, Auxin and ABA, SA and JA) in plant development. Regulation of Flowering, Plant photoreceptors and light signal transduction, vernalization, Circadian Rhythms.

Unit IV (14 Lectures) : Abiotic Stress Responses: Salt, Cold, Heat and Drought. Biotic Stress Responses. Molecular Biology of Plant-pathogen Interactions, Molecular Biology of *Rhizobium* and *Agrobacterium*- Plant interaction. Role of programmed Cell Death in Development and Defense.

Suggested Referances

Buchanan, B.B., Gruissem, W. and Jones R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley and Blackwell Publications.

Slater, A., Scott, N.W., and Fowler, M.R. 2003. *The Genetic Manipulation of Plants. Plant Biotechnology Oxford, England: Oxford University Press.*

Walker, J.M., Rapley, R. 2008. *Plant Biotechnology and Genetics: Principles, Techniques and Applications.*

MBB 602	Plant Genome Engineering	3+0

Theory

Unit I (14 Lectures) : Conventional versus non-conventional methods for crop improvement; Present status and recent developments on available molecular marker, transformation and genomic tools for crop improvement.Genetic engineering for resistance against abiotic (drought, salinity, flooding, temperature, *etc*.) and biotic (insect pests, fungal, viral and bacterial diseases, weeds, *etc*.) stresses; Genetic Engineering for increasing crop productivity by manipulation of photosynthesis, nitrogen fixation and nutrient uptake efficiency; Genetic engineering for quality improvement (protein, essential amino acids, vitamins, mineral nutrients, *etc*.); edible vaccines, *etc*.

Unit II (12 Lectures) : Recent developments in plant transformation strategies; Role of antisense and RNAi-based gene silencing in crop improvement; Regulated and tissue-specific expression of transgenes for crop improvement;

Unit III (12 Lectures) : Gene stacking; Pathway engineering; Marker-free transgenic development strategies; Genome editing: principles and methods, Development of genome edited plants; High throughput phenotyping of transgenic plants.

Unit IV (10 Lectures) : Field studies with transgenic crops; Environmental issues associated with transgenic crops; Food and feed safety issues associated with transgenic crops; Risk assessment of transgenic food crops.

Suggested Referances

Christou P and Klee H. 2004. *Handbook of Plant Biotechnology*. John Wiley & Sons.

Stewart Jr, C.N. 2016. *Plant Biotechnology and Genetics: Principles, Techniques, and Applications*. John Wiley & Sons.

Kirakosyan A and Kaufman PB. 2009. *Recent Advances in Plant Biotechnology* p. 409. Dordrecht: Springer.

MBB 603	Plant Omics and Molecular Breeding	3+0

Theory

Unit I (12 Lectures) : Complex traits and genetic architecture, Mapping genes and QTLs, statistical concepts in QTL mapping, high-throughput genotyping using automated platforms, genetic and physical mapping of genomes, study of population structure and kinship, association genetic analysis of QTL, case studies on QTL mapping using different approaches, map-based of cloning genes and QTLs – case studies.

Unit II (12 Lectures) : Marker Assisted Breeding (MAB): Principles and methods, marker assisted foreground and background selection, marker assisted recurrent selection, whole genome selection, case studies in MAS, requirement for successful marker assisted breeding, cost of MAB.

Unit III (12 Lectures) : Concepts and methods of next generation sequencing (NGS), assembly and annotation of NGS data, genome resequencing, DNA sequence comparison, annotation and gene prediction. Genome-wide insertion mutagenesis and its use in functional genomics, transcriptome profiling using microarrays and deep sequencing, study of methylome and its significance, proteome analysis using mass spectrometry, crystallography and NMR, analysis of proteome data, study of protein- proteininteractions.

Unit IV (12 Lectures) : Study of the metabolome, use of 1D/2D NMR and MS in metabolome analysis, multivariate analysis and identification of metabolite as biomarkers, study of ionome using inductively coupled plasma – mass spectroscopy (ICP-MS), correlating the data from genome, transcriptome, proteome, metabolome and ionome with phenome.

Suggested Referances

Speicher, D.W. (Ed.). 2004. *Proteome analysis: interpreting the genome*. Elsevier.

Tomita, M. and Nishioka, T. (Eds.). 2006. *Metabolomics: the frontier of systems biology*. Springer Science and Business Media

Horst, L. and Wenzel, G. (Eds.). 2007. *Molecular marker systems in plant breeding and crop improvement* (Vol. 55). Springer Science and Business Media.

Stewart C.N. 2008. *Plant Biotechnology and Genetics: Principles, Techniques and Applications*.

Singh, B.D. and Singh, A.K. 2015. *Marker-Assisted Plant Breeding: Principles and Practices* Springer (India) Pvt. Ltd.

MBB 604	Commercial Plant Tissue Culture	2+0

Theory

Unit I (8 Lectures) : Micro-propagation of commercially important plant species; plant multiplication, hardening, and transplantation; genetic fidelity; scaling up and cost reduction; bioreactors; synthetic seeds; management and marketing.

Unit II (8 Lectures) : Production of useful compounds *via*, biotransformation and secondary metabolite production: suspension cultures, immobilization, examples of chemicals being produced for use in pharmacy, medicine and industry.

Unit III (9 Lectures) : Value-addition by transformation; development, production and release of transgenic plants; patent, bio-safety, regulatory, environmental and ethical issues; managementand commercialization.

Unit IV (7 Lectures) : Project planning and preparation, economics (entrepreneurship, cost profit ratio), government policies (incubators, different facilitation projects, loan opportunities). Some case studies on success stories on commercial applications of plant tissue culture. Visits to some tissue culture based commercial units/industries.

Suggested Referances

Honda, H., Liu, C., Kobayashi, T. 2001. *Large-Scale Plant Micropropagation*. In: Zhong J.J. *et al.* (eds) *Plant Cells. Advances in Biochemical Engineering/ Biotechnology*, vol 72. Springer, Berlin, Heidelberg.

Bhojwani SS and Razdan MK. 1986. *Plant tissue culture: theory and practice* (Vol. 5). Elsevier.

MBB 605	Plant Microbe Interaction	2+0

Theory

Unit I (8 Lectures) : Microbial communities in the soil and atmosphere, Community dynamics and population interactions with particular reference to plant–microbe and microbe- microbe interactions leading to symbiotic, associative, endophytic and pathogenic interactions, effects of microorganisms on plants, effects of plants on microorganisms. Recognition processes and signal exchange, Molecular aspects of Plant Growth Promoting Rhizobacteria (PGPR), Symbiotic diazotrophs: Rhizobia and association with legumes. Mycorrhizal associations: Ectomycorrhizae, Endomycorrhizae with particular emphasis to AM fungi, Ectendomycorrhizae. Biocontrol agents and their action, endophytes associations

Unit II (8 Lectures) : Enzymes, toxins, pili, siderophores, secretion systems of microbes and plants determining soil health, nutrient availability and uptake defense responses in plants: pamp-triggered immunity, effector-triggered susceptibility, qualitative resistance, R genes, structure and function, effector-triggered immunity, regulation of plant cell death, plant hormones in immunity, Plant parasite interactions and its molecular basis and impact on plant functions including photosynthesis, respiration, nitrogen metabolism and translocation

Unit III (8 Lectures) :Quorum sensing in bacteria, understanding microbiome, phytobiomes, dynamics, Applied and ecological aspects of symbioses and pathogen defense, techniques to study plant microbe interaction including microbe tagging, metagenomics and use of organismal databases to identify genes involved in interactions. Industrial application of agriculturally important microbes.

Unit III (8 Lectures)

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

Suggested Referances

Rangaswamy, G. Bhagyaraj. 1993. *Agricultural Microbiology*, Prentice Hall India.

Stacey, G., and Keen, N.T. (Eds.). 1996. *Plant-microbe interactions.* Springer Science & Business Media.

Dickinson M. 2005. *Molecular Plant Pathology*. Bios Scientific Press, Taylor and Francis group.

Kosuge T and Nester EW. 1989. *Plant-Microbe Interactions: Molecular and Genetic Perspectives.*Vols I-IV. McGraw Hill.

González MBR and Gonzalez-López J. (Eds.). 2013. *Beneficial plant-microbial interactions: ecology and applications*. CRC press.

MBB 606	RNA Biology	1+0

Theory

Unit I (4 Lectures) : RNA structure, functional evolution: RNA structure, types of RNA and function; Genome evolution- RNA as genetic material to regulatory molecule, Non-Coding RNAs, structure, function and regulation.

Unit II (4 Lectures) : RNA synthesis, processing and regulation: transcription and its regulation in prokaryotes and eukaryotes; RNA splicing and editing; Translation and its regulation in prokaryotes and eukaryotes; Genome regulation: Prokaryotic-attenuation, ribozymes, aptamers, riboswitches, CRISPER-Cas; eukaryotic-Exon skipping, nonsense-mediated decay, RNAi, Long non-coding RNA.

Unit IV (4 Lectures) : Epigenetic regulation. RNA-based gene silencing technologies and their applications for crop improvement

Suggested Referances

Elliott, D., and Ladomery, M. 2017. *Molecular biology of RNA.* Oxford University Press.

Rao, M.R.S. (Ed.) 2017. *Long Non-Coding RNA Biology*, Springer,

Donald, C.R., Hannon, G., Ares, M. and Nilsen, T.W. 2011. *RNA: A Laboratory Manual,* CSHL Press.

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

MBB 607	Plant Hormones and Signaling	2+0

Theory

Unit I (12 Lectures) : Hormone Biosynthesis, Metabolism and its Regulation: Auxin biosynthesis and metabolism, Gibberellin biosynthesis and Inactivation, Cytokinin biosynthesis and metabolism, Ethylene biosynthesis, Abscisic acid biosynthesis and metabolism, Brassinosteroid biosynthesis and metabolism. Salicylic acid and jasmonate biosynthesis and metabolism.

Unit II (12 Lectures) : Functioning of hormones in plant growth and development: Transport of Auxins, Induction of vascular tissues by Auxin, Hormones and the regulation of water balance, seed development and germination, Hormonal control of day length and senescence.

Unit III (12 Lectures) : Action of Hormones: Hormones in defense against insects and disease; Role of jasmonates, salicylic acids and peptide hormones for defense, growth, development and reproduction; Methods of plant hormone analysis. NPR 1 dependent Salicylic acid signaling, PAMP and effector triggered immunity, systemic acquired resistance and SA signaling.

Unit IV (12 Lectures) :Hormone Signal Transduction: Auxin metabolism, transport and signal transduction, Cytokinin types, synthesis, metabolism, transport and signal transduction, Gibberellin biosynthesis, transport, signal transduction in stem elongation & Leaf growth, Ethylene metabolism, perception and signaling in seedling growth and development, Ethylene signal transduction in fruits and flowers, Abscisic acid metabolism, transport and signal transduction in nuclear gene expression and stomatal responses. Brassinosteroid biosynthesis, catabolism and signal transduction. Strigalactone biosynthesis, transport and signaling in plant parasitism and symbiosis. Methods of Plant Hormone analysis: Quantitative analysis of plant hormones based on LC/MS.

Suggested Referances

Davies Jr. F. *et al*. 2017. Hart Mann and KRster's. *Plant Propagation: Principles and Practices.* Pearson.

MBB 608	Computational and Statistical tools in Biotechnology	1+1

Theory

Unit I (8 Lectures) : Basic molecular biology; introduction to the basic principles of structure/function analysis of biological molecules; genome analysis; different types and classification of genome databases (e.g. HTGS, DNA, Protein, EST, STS, SNPs, Unigenes, *etc*.)

Unit II (8 Lectures) : Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing; Resampling techniques – Bootstrapping and Jack- knifing; Markov Models. Hidden Markov Models, Bayesian estimation and Gibbs sampling.

Unit III (8 Lectures) : DNA sequence retrieval system, various DNA and protein sequence file formats, Basic concepts of similarity searching and sequence alignments, pair wise and multiple sequence alignments, DNA sequence analysis, different gene prediction models and gene annotation tools,

Unit IV (8 Lectures) : Protein sequence analysis and structure prediction, comparative genome analysis, phylogenetic analysis, gene expression analysis tools, programming languages and their applications in bioinformatics

Practicals:

- Different Types of Databases and Database Search and Retrieval,
- DNA and Protein Sequence Analysis,
- Similarity Searching and Multiple Alignments,
- Gene Annotation,
- Phylogenetic Analysis,
- Sequence Analysis,
- Protein Structure Prediction,
- Analysis of Microarray Data,
- Programming Languages in Bioinformatics.

Suggested Referances

Xiong J. 2012. *Essential Bioinformatics*, Cambridge University Press.

Andreas, D.B., and Ouellette B.F.F., (Eds) 2004. *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* 3rd Edition, Wiley Interscience.

Mount D. 2004. *Bioinformatics: Sequence and Genome Analysis*, 2nd Edition. By, CSHL Press.

Augen J. 2004. *Bioinformatics in the Post-Genomic Era: Genome, Transcriptome, Proteome, and Information-Based Medicine*.

Galperin M.Y. and Koonin E.V. (Eds) 2003. *Frontiers in Computational Genomics*.

SUPPORTING/ MINOR COURSES FOR Ph. D. DEGREE PROGRAMMES

AGRICULTURAL ECONOMICS

SL NO	COURSE NO	COURSE TITLE	CREDIT HOURS
MINOR COURSES			
01	AEC 601	Advanced Production Economics	1+1
02	AEC 602	Operations Research	0+1

AEC 601	**Advanced Production Economics**	**1+1**

Theory

Agricultural production-Relationship between farm planning and production economics-scope of agricultural production and planning methods/ procedures in agro-economic research and planning. Productionfunctions, components, assumptions, properties and their economic interpretation-concepts of homogeneity, homotheticity, APP, MPP, elasticities of substitution and their economic relevance. Production relationsoptimality. Commonly used functional forms, nature, properties, limitations, estimation and interpretation-linear, Spillman, Cobb Douglas, quadratic, multiplicative (Power) functional forms-Translong and Transcendental functional forms-CES, production functional forms- Conceptual and empirical issues in specification, estimation and application of production functions- Analytical approaches to economic optimum Economic optimumdetermination of economic optimum with production function analysis, input use behavior. Decision making. Decision making with multiple inputs and outputs-Decision making with no risk-cost of wrong decisions. Cost curves. Duality of profit and cost functions-principles and derivation of demand and supply functions. Technology, input use and factor shares, effect of technology on input use. Decomposition analysis. Factor shares estimation methods-Economic efficiency in agricultural production technical, allocative and economic efficiency-measurement Yield gaps analysis-concepts and measurement. Risk and uncertainty in agriculture incorporation of risk and uncertainty in decision-making-risk and uncertainly and input use level-risk programming. Economic analysis of risk mitigating measures, economics of Intergraded farming system.

Practicals

Estimation of different forms of production-Optimal input and product choice from estimated functions-Derivation of demand and supply functions-Estimation of cost functions and interpretations-Estimation of factor shares from empirical functions estimated-Estimating production functions incorporation of technology-Estimation of efficiency measures- Stochastic, probabilistic and deterministic frontier production functions- Simulation models for agricultural production decisions.

Suggested References

Gardner B L and Rausser G C 2001. Hand Book of Agricultural Economics. Vol. I A Agricultural Production. Elsevier.

Palanisami K P, Paramashivam and Ranganathan C R 2002, Agricultural Production Economics: Analytical Methods & Applications Associated Publishing Co. Heady E O, Economics of Agricultural Production and Resource use. Prentice hall.

S.S. Johl & J.R. Kapoor, Fundamentals of farm Business Management.

V.T. Raju & D.V.S. Rao, Economics of Farm Production and Management. Damodar N. Gujarati, and Dawn C. Porter, Basic Econometrics 5 th Edition.

AEC 602	Operations Research	0+1

Practicals

Introduction and nature of operations research. History of operations research, characteristics of operations research. Stages in development of operations research, project-formulation and components of a problem. Deterministic models, Linear programming and i ts applications. Transportation models, Dynamic programming. Constrained and unconstrained non-linear programming methods, multiple objective decision making. Stochastic models, Markov chains, Bayesian analysis. Theory of inventory management: Economic ordering quantity and relate4d issues, maintenance and replacement problems Network flow problems. PERT and critical path methods. Queuing theory. Game theory-business games, Monte Carlo method, Simulations, Heuristic programming Application of OR techniques to agriculture. Numerical examples and case studies in the following OR problems. Formulation of OR problems and solving them using various steps. Application of linear programming and dynamic programming, Inventory problems, networks flow problems, PERT and critical path methods, queuing problems, stochastic and Markov chains, unconstrained and constrained non-linear programming models. Application of operations research to specific agricultural problems.

Suggested References

Gardner B L and Rausser G C 2001. Hand Book of Agricultural Economics. Vol. I A Agricultural Production. Elsevier.

Palanisami K P, Paramashivam and Ranganathan C R 2002, Agricultural Production Economics: Analytical Methods & Applications Associated Publishing Co.

Heady E O, Economics of Agricultural Production and Resource use. Prentice hall.

S.S. Johl & J.R. Kapoor, Fundamentals of farm Business Management.

V.T. Raju & D.V.S. Rao, Economics of Farm Production and Management.

Damodar N. Gujarati, and Dawn C. Porter, Basic Econometrics 5 th Edition.

AGRICULTURAL EXTENSION

SL NO	COURSE NO	COURSE TITLE	CREDIT HOURS
MINOR COURSES			
01	AEX 601	Advances in Training Technology	1+1
02	AEX 602	Organizational Development	1+1
03	AEX 603	Media Management	1+1

AEX 601	Advances in Training Technology	1+1

Theory

Paradigm shift in training-learning scenario, Training Approaches- Experiential learning-laboratory-organization development (system) approaches; Training Design, Designing an effective training programme, Harmonizing training needs, Course Objective, content and methods. Designing an effective training session-the semantics involved, Designing experiential training sessions, simumation exercises, and openness in training transaction-managing delimmas, ambivalence and conflicts and confusion (for both trainers and trainees). Recent Training Techniques for understanding and facilitation, team building, group dynamics, motivation and empowerment, laboratory methods: micro-lab process work, and sensitivity training, Psychological instruments as training tools: TAT, Inventories, Cases, etc. Participatory Training Techniques-Lecutre, Brainstorming, Group discussion and Training Games. Role Play, Psychodrame, Coaching, Counseling, etc., Trainer's roles and dilemmas, Factors Affecting Training Effecitveness and Training Evaluation.

Practicals

Techniques of participatory training need assessment. Formulation of Course Objective, design of training programmes. Simulation exercises. Participatory training methods-Role Play & Brainstorming, Group discussion and Counseling and Conducting experiential learning sessions. Training evaluation-Techniques of Knowledge, Skill & Attitude evaluation. Visit to training institutions and study of training technologies followed.

Suggested Regerences

FAO Publication, 2007., Horticultural Marketing –A Resource and Training Manual for Extension Officers –FAO,

C. Karthikeyan Etal, A Text Book of Agricultural Extension Management

AEX 602	Organizational Development	1+1

Theory

Introduction to organizations: Concept and characteristics of organizations, Organizational Behaviour-Context and concept-levels of organizations-formal and informal organizations, Theories of organizations: Nature of organizational theory-classical theories-features of Bureaucracyadministrative theory and Scientific

management-Neo- classical theories-the human relations movement-modem theory. Systems approach to study organization needs and motives-Attitude, values and ethical behaviouralienation and work-work motivation-communication and interpersonal behaviour-organization communication-leadership behaviour-decision making, problem solving techniques-organizational climate-change proneness and resistance to change, Organizational change, Organizational structure-Process in organizing-Dimension of Motivation Climate. Departmentation-Span of Management-Delegation of authority-Centralization and decentralization-line and staff organization-functional organization-divisonalisation-Project organization-Matrix organization- free form organization-top management structure. Individual behaviour in organization. Fundamentals of Human relations and Organizational behaviour, Groups and teams-Organisational culture and performance. Dynamics of Organization behaviour-leadership conflict situations and inter group behavior-Organisational Development-Factors affecting organization effectiveness. Creativity, leadership, motivation and organization development.

Practicals

Analysis of organization in terms of process-attitudes and values, motivation, leadership. Simulation exercises on problem-solving- Study of organizational climate in different organizations. Study of organizational structure of development departments, Study of departmentalization, span of control delegation of authority, decisions making patterns, Study of individual and group behaviour at work in an organization. Conflicts and their management in an organization. Comparative study of functional and non-functional organsiations and drawing factors for organizational effectiveness.

Suggested References

Singh Ashok K., Extension strategies for Agriculture and Rural Development

Dr. T. Radhakrishnan, Dr. M. Iseael Thomas, Dr. L. Nirmal., 2009., Advance and Challenges in Agricultural Extension and Rural Development

A.K. Singh, 2012., Agricultural Extension Impact and Assessment

B.S. Hansra and K. Vijayaraghavan ., 2003., Agri Business and Extension Management

Tripathi., A Text Book of Research Methodolgy in Social Sciences

AEX 603	Media Management	1+1

Theory

Media Management-Introduction, Definition, Principles and Significance of Management. Media Ownership patterns in India.- Proprietorship, Partnership, Private Ltd, Public companies, Trusts, Cooperatives, Religious Institutions (Societies) & Franchisees (Chains). Marketing Function-Product, Price, and Placement & Promotions. Mass Communication-Meaning, Concept, Definition and Theories of Mass Communication. The Mass Media-History, functions, uses and Theories of Media. Journalism-Meaning, definition, Scope, functions and different types of Journalism. Journalism as communication tool. Farm Journalism-meaning and Developments in Farm Journalism in India. Different problems with Farm Journalism. Print Media-History, the role ofthe press, news, Types of News, electronics of News and Sources of News, the making of newspaper & magazines, press codes and ethics, Media Laws. News story-

Principles of writing, structure a news story, procedure in writing the news story and the elements of style. Success stories & feature articles-writing for success & feature articles, Types of Feature articles. Information materials-Types of information materials and user. Techniques in book Publishing. Editing- Principles, Tools & Techniques and art of Proof Reading-Techniques, Measuring Readability of writing. Electronic Media-Role and Importance of Radio-History, Radio Role in TOT, writing and presentation techniques, Different Programmes of Farm Broadcast, developing content for farm broadcast, Role of FM Radio in Agriculture, Ethics of Broadcasting, Broadcasting Policy and code. Community Radio-Concept, meaning, role in TOT, Cases of Community radio. Television-History-Role in TOT, Fundamentals of Te1evision Production, Techniques of Script writing for TV, Visual Thinking, language & Style, Farm Telecast programmes, cable and satellite TV and their impact, Ethics of Telecasting, policy and code. Video Production Technology- Potential and its utilization, Typology of farm Video production, Types of Video Production and equipment used in the production, Procedure 'or Technique of video production. Cassette Technology-Role in TOT, Techniques of production of cassettes for the farming community. Traditional Media- Role of Folk Media in TOT and integration with electronic media. Advances in communication Technology- Management of Agricultural Information System (MArS). Use of computers in Agriculture-Application of IT in Agriculture. Use of Modern Communication Medium-Electronic Video, Teletext, tele conference, Computer assisted instruction, Video conferencing, -Features, Advantages, Limitations and risk factory involved in New Media. Designing and developing of communication and media strategy for developmental programmes. Online journalism scope and importance.

Practicals

Writing for Print Media-Writing News / Success Stories / Feature articles for different topics related to Agriculture & allied fields. Exercise of editing & proofreading the Farm News for News papers-different types of intro and leads. Exercise of Writing for Radio, TV, Preparation of story board for farm Video Production-Script writing for Radio and T.Y. Visit to media management organizations for studying the principles, procedures and processes in managing the media. Participation and Interaction through video conference. Developing communication & Media Strategy for selected developmental programme / activity.

Suggested References

Heather, N., FAO Publication., 2007., Communication in Extension A Teaching and Learning Guide FAO

Dubey, S.K. Sah, Uma, Singh A.K., 2011., Linkage Perspective in Agricultural Extension Shruti ., 2015., Instant Extension Education (for JRF)

Dr. G. Pankajam., 2000., Extension Third Dimension of Education Lahiri B., Mukhopadhyaya, Adhikari M.M., 2012., Mass media in Agricultural Extension

AGRICULTURAL MICROBIOLOGY

SL NO	COURSE NO	COURSE TITLE	CREDIT HOURS
MINOR COURSES			
01	AMB 601	Advances in Fermentation Technology	1+1
02	AMB 602	Current Topics in Soil Microbiology	1+1
03	AMB 603	Biology and Production of Mycorrhiza	2+1

AMB 601	**Advances in Fermentation Technology**	**1+1**

Theory

An overview of fermentation-current status of fermentation industry. Fermentor design, high performance bioreactors, mass and energy transfer in bioreactors. Instrumentation and control in fermentors-online measurement systems, computer application. Media for microbial fermentation; Criteria in media formulation. An overview of downstream processing. New strategies for isolation of industrially important microbes and their genetic manipulations; Microbial production of health care products. Antibiotic fermentation research; steroid transformation. Recent developments on production of primary and secondary metabolites, Treatment of biological wastes, microbial inoculants and enzymes for waste treatment. Yeast technology-classification, genetics, strain improvement for brewing, baking and distilleries and topics of current interest in fermentations.

Practicals

Industrially important microbes and their genetic manipulations, F ermeptation by improved strains of yeast for production of alcohol and beer, Microbial production of important antibiotocs, enzymes and organic acids, Bioremediation of industrial effluents.

Suggested References

Peter F. Stanbury, Allan Whitaker and Stephen J Hall Principles of Fermentation TechnologyD. Perlman Microbial Technology Carlos Ricardo Soccol,

Ashok Pandey, Christian Larroche., 2013 Fermentation Processes Engineering in the Food Industry

Brian McNeil, Linda M. Harvey, 2008, Practical Fermentation Technology

Antonio Mendez-Vilas, 2014 Industrial, medical and environmental applications of Microorganisms

Goldberg E, 1996, Handbook of Downstream processing

Verrall, 2013, Downstream Processing of natural products a practical Handbook

B. Sivasankar, Bioseparations: Principles and Techniques [print replica]Kindle Edition

Henry C Vogel, Celeste M Todaro Fermentation and biochemical Engineering Handbook Principles process Design and Equipment Microbial inoculants and Biofertilizer Technology Saujanya books Christopher Boulton, David Quain Brewing yeast and fermentation

AMB 602	Current Topics in Soil Microbiology	1+1

Theory

Molecular ecology and biodiversity of soil microorganisms; Survival and dispersal of microorganisms. Microbial successions and transformation of organic matter; Role of microorganisms in soil fertility. Bioremediation of polluted soils; Biological control of Soil bOI11e Plant Pathogens. Other topics of current interest.

Practicals

Activities of soil enzymes; Study of chemoautotrophic bacteria, Heterotrophic nitrification; Microbial transformation ofxenobiotics. Study of microbial successions.

Suggested References

Koltai, Hinanit, Kapulnik, Yoram , Arbuscular mycorrhizas: Physiology and function

Mukerji K.G. Manoharachary, C. Chamola B P., Techniques in Mycorrhizal Studies

Declerck, Stephane, Strullu, Desire-Georges, Fortin, Andre., In vitro culture of mycorrhizas

Tancredo Souza., Handbook of Arbuscular mycorrhizal fungi 1st ed. 2015, kindle Edition

AMB 603	Biology and production of Mycorrihizra	2+1

Theory

Type of mycorrhizae-ecto, vesicular-arbuscular, Ericoid and orchidaceous mycorrhizae, their occurrence, distribution and significance in natural ecosystem. Ectomycorrhizae-fungi involved, their morphology ecology and physiology. Methods of inoculation-plant response to inoculation-mechanism of improved plant growth. Production of the VA mycorrhizae inoculum and i ts application. Vesicular-arbuscular mycorrhizae taxonomy of the fungi, morphology and histology, quantification in plnat roots and in soil. Isolation, axenic and pot culture. Procedures for inoculation, plant response to colonization. Physology and ecology of the symbiosis. Biological interactions with other soil flora and fauna. Mass multiplication techniques. Exploitation of mycorrhizae in agriculture, horticulture and forestry.

Practicals

Quantification of mycorrhizae in plant roots: methods for the recovery of mycorrhizal propegules from soil: spore germination and axenic culture of endomycorrhizae; production of endomycorrhizal inoculum; evaluation of plant responses to mycorrhizal inoculation Study tour to collect samples for isolation and identification of mycorrhizal fungi.

Suggested References

The mycorrhizae Diversity, Ecology and Applications 2008, M. Tiwari & S.C. Sati (Auditors), Daya Publishing House Delhi.

Fundamentals of Mycorrhizal biology and Biotechnology 2002, Ramarao Pannuri, Agrotech Publishing Academy, Udaipur

AGRONOMY

SL NO	COURSE NO	COURSE TITLE	CREDIT HOURS
MINOR COURSES			
01	AGR 601	Current Trends in Agronomy	3+0
02	AGR 602	Crop Ecology	2+0
03	AGR 603	Advances in Crop Growth and Productivity	2+1
04	AGR 604	Integrated Farming Systems	2+0

AGR 601	**Current Trends in Agronomy**	**3+0**

Theory

Unit I : Agro-physiological basis of variation in yield, recent advances in soilplant-water relationship.

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

Unit III : Crop residue management in multiple cropping systems; latest developments in plant managementMechanizationin crop production: modern agricultural precision tools and technilogies, weed management, cropping systems, grassland management, agro-forestry, allelopathy.

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

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

Suggested Referances

Agarwal RL. 1995. *Seed Technology*. Oxford & IBH.

Dahiya BS and Rai KN. 1997. *Seed Technology*. Kalyani.

Govardhan V. 2000. *Remote Sensing and Water Management in Command Areas Agroecological Prospectives*. IBDC.

ICAR. 2006. *Hand Book of Agriculture*. ICAR.

Narasaiah ML. 2004. *World Trade Organization and Agriculture*. Sonali Publ.

Palaniappan SP and Annadurai K. 2006. *Organic Farming - Theory and Practice*. Scientific Publ.

Sen S and Ghosh N. 1999. *Seed Science and Technology*. Kalyani.

Tarafdar JC, Tripathi KP and Kumar M. 2007. *Organic Agriculture* Scientific Publ.

Kumar, R, Swarnkar KS, Singh KS and Narayan S. 2016. *A Text Book of Seed Technology*. Kalyani Publication.

Reddy SR and Prabhakara G. 2015. *Dryland Agriculture*. Kalyani Publishers.

Gururajan B, Balasubhramanian R and Swaminath V. 2013. *Recent Strategies on Crop Production*. Kalyani Publishers.

Venkateswarlu B and Shanker Arun K. 2009. *Climate change and agriculture: Adaptation and mitigation strategies*. *Indian Journal of Agronomy* **54**(2): 226-230.

AGR 602	Crop Ecology	2+0

Theory

Concept of crop ecology, agricultural systems, ecology of cropping systems, principles of plant distribution and adaptation, crop and world food supply Agro-ecological regions and agro-climatic zones of India and Karnataka. Ecosystem characteristics, types and functions, terrestrial ecology, flow of energy in ecosystem, ecosystem productivity, biomass, succession and climax concept. Ecological factors affecting crop production. Physiological response of crop plants to light, temperature, CO2, moisture and solar radiation; influence of climate on photosynthesis and productivity of crops; effect of global climate change on crop production. Exploitation of solar energy in crops; vertical distribution of temperature; efficiency in crop production. Competition in crop plants; environmental pollution, ecological basis of environmental management and environment manipulation through agronomic practices; improvement of unproductive lands through crop selection and management.

Suggested References

Chadha, K.L. and Swaminathan, M.S. 2006. Environment and Agriculture. Malhotra Publ. House. Critchfield, H.J. 1995. General Climatology. Prentice Hall of India.

Hemantarajan, A. 2007. Environmental Physiology. Scientific Publ. Kumar,

H.D. 1992. Modern Concepts of Ecology. 7th Ed. Vikas.Publ. Lal, D.S. 1998. Climatology. Sharda Pustak Bhawan.

Lenka, D. 1998. Climate, Weather and Crops in India. Kalyani Publ. Menon, P.A.1991. Our Weather. National Book Trust Publ.

Sahu, D.D. Agrometeorology and Remote Sensing: Principles and Practices. Sharma, P.D. 1998. Ecology and Environment. Rastogi Publ.

Varshneya, M.C. and Balakrishana Pillai, P. 2003. Textbook of Agricultural Meteorology. ICAR Publ.

Global Warming (Fourth edition) by Johm Houghton, Cambridge Press

AGR 603	Advances in Crop Growth and Productivity	2+1

Theory

Plant density and crop productivity; plant and environmental factors, yield, plant distribution, strategies for maximizing solar energy utilization; leaf area; interception of solar radiation and crop growth; photosynthesis: the photosynthetic apparatus, factors essential for photosynthesis; differences in photosynthetic rates among and within species; physiological limitations to crop yield; solar radiation concept and agro-techniques for harvesting solar radiation. Growth analysis concept, CGR, RGR, NAR, LAI, LAD, LAR; validity and limitations in interpreting crop growth and development; growth curves: sigmoid, polynomial and asymptotic; root systems; root-shoot relationship; principles involved in inter and mixed cropping systems under rainfed and irrigated conditions; concept and differentiation of inter and mixed cropping; criteria in assessing the yield advantages. Competitive relationship and competition functions; biological and agronomic basis of yield advantage under intercropping; physiological principles of dry land crop production, constraints and remedial measures; heat unit

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

Practicals

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

Suggested References

Donald, L. Smith and Chantal, Hamel (Eds). 2002. Crop Yields –Physiological Processes. Springer.- Verlag, Berlin Edward, Arnold, John, H., Thornley, M. and Johnson, I.R. 1997. Plant and Crop Modeling: A Mathematical Approach to Plant and Crop Physiology. Blackburn Press.

Gardner, F.P., Pearce, R.B. and Mitchell, R.L. 1988. Physiology of Crop Plants. Scientific Publishers, Jodhpur.

Goudriaan, J. and Van Laar, H.H. 1995. Modelling Potential Crop Growth Processes. (Textbook with Exercises) Series: Current Issues in Production Ecology. Vol. II. Kluwer.

Hay, R.K.M. and Porter, J.R. 2006. The Physiology of Crop Yield. Blackwell Publisher.

Hunt, R. 1982. Plant growth curves: the functional approach to plant growth analysis. London: Edward Arnold Vos, J., Marcelis, L.F.M., Visser, P.H.B.D., Struik, P.C. and Evers, J.B. (Eds.). 2007. Functional- Structural Plant Modelling in Crop Production. Vol. XXII. Springer.

Jone, A., Baligar F., 1991 Growth and Microal Horticultural field crops Marcel Decker publisher PP 488

Sottari A and Sinclair T R 2012 Modeling physiology of crop development growth and yield CABI Hoswardy PP 368

Fageria H K, Baligar V C., and Clark R B., 2016 Physiology of crop production CRC press PP 356.

AGR 604	Integrated Farming Systems	2+0

Theory

Farming systems; definition and importance; classification of farming systems according to type of rotation, intensity of rotation, degree of commercialization, water supply; enterprises in farming systems. Concept of sustainability in farming systems; efficient farming systems; natural resources-identification and management. Farming system approach, concept of integration-Production potential of different components of farming systems; interaction and mechanism of different production factors; stability in different systems; eco-physiological approaches to farming systems. Simulation models for farming systems; nutrient recycling in farming systems-sustainability, input rationalisation; preparation of different farming systems models; New concepts and approaches of farming systems and cropping system. Farming system approach for

sustainability; Energy concept in farming systems-evaluation based on energy relations. Case studies of different farming systems

Suggested References

Behera, U.K., Das, T.K. and Sharma A.R. 2009. Manual on Multicriteria Decision Making and Optimization Methodology for Sustainable Farming. Division of Agronomy, IARI, New Delhi.

Mahapatra, I.C., Mahapatra, P.K. and Batra, P.K. 2002. Field Manual for On- farm Adaptive Research. Agroecosystem Directorate (Rainfed farming). National Agricultural Technology Project. Central Research Institute for Dryland Agriculture, Hyderabad.

Malcolm, Hall. 2001. Farming Systems and Poverty: Improving Farmers Livelihood in Changing World. FAO and World Bank, Rome and Washington, D.C.

Palaniappan, S.P. and Sivaraman, K. 1996. Cropping Systems in the Tropics: Principles and Management. New Age Publ.

Panda, S.C. 2004. Cropping Systems and Farming Systems. Agribios.

Raman, K.V. and Balgur u, T. 1992. Farming Systems Research in India: Strategies for Implementation. Proceedings of the National Workshop, November 25-28, 1991, NAARM, Hyderabad, India

Rangaswamy, A., Annadurai, K., Subbain, P. and Jayanti, C. 2002. Farming Systems in the Tropics, Kalyani Publishers.

Sankaran, S. and Mudaliar, T.V.S. 1997. Principles of Agronomy. The Bangalore Printing & Publ. Co.

Singh, A.K., Sharma, S.K., Batra, P.K. and Sharma, N.K. 2003. Instruction Manual for On-farm Research (Cropping Systems). Project Directorate for Cropping Systems Research, Modipuram, Meerut.

CROP PHYSIOLOGY

SL NO	COURSE NO	COURSE TITLE	CREDIT HOURS
MINOR COURSES			
01	CPH 601	Functional Genomics and Genes Associated With a Few Physiological Processes	2+0
02	CPH 602	Signal Perceptions and Transduction and Regulation of Physiological Processes	2+0
03	CPH 603	Molecular Approaches for Improving Physiological Traits	2+1
04	CPH 604	Advanced Techniques in Plant Physiology	0+2
05	CPH 605	Climate Change and Crop Growth	2+0
06	CPH 606	Molecular Physiology of Mineral Nutrient Acquisition, Transport and Utilization	1+1

CPH 601	**Functional Genomics and Genes Associated With a Few Physiological Processes**	**2+0**

Theory :

UNIT I : Gene discovery: Finding Genes in Complex Plant System, Constructing Gene Enriched Plant Genomic Libraries, *In Silico* Prediction of plant Gene Function, Quantitative Trait Locus Analysis as a Gene Discovery Tool.

UNIT II : Genetic tools for plant development- Understanding the importance of mutants in unraveling the physiological processes – T-DNA insertion mutants, Gain in function, Transposon mutagens, Transposition, Physical and Chemical mutagenesis, Gene and Enhancer Traps for Gene Discovery, High-Throughput TAIL-PCR as a Tool to identify DNA Flanking insertions, High-Throughput TILLING for functional Genomics.

UNIT III : Gene knock out approaches: Antisense technology, Virus induced gene silencing (VIGS), Custom Knock-outs with Haripin RNA-mediated Gene Silencing and other silencing tools, Complementation studies, DNA micro arrays.

UNIT IV : Gene Over expression approaches: Vector Construction for Gene Overexpression as a Tool to Elucidate Gene Function; Transient expression, Transgenics.

UNIT VI : Proteomics: Networking of Biotechnology for interpreting gene functions. Yeast two hybrid systems to study protein –protein interaction to study gene functions, Proteomics as a Functional Genomics Tool, Crystallographic and NMR approaches to determine protein structures.

UNIT V: Functional characterization of genes associated with important cellular processes influencing crop growth and development.

UNIT VI : Case studies of genes controlling photosynthesis, respiration, photorespiration, fatty acid biosynthesis, nutrient uptake, flowering, seed protein quality and quantity.

Suggested Referances

Benjamin Lewin, 2004. Genes VIII. Publ. Pearson Prentice Hall.

Taiz L & Zeiger E. 2006. Plant Physiology. 4th Ed. Sinauer Associates.

The handbook of plant functional genomics by Gunter katl and kahid meksem published by wily Blackeves

Bioinformatics and functional genomics. by J.Pevnsen

Functional genomics methods. by Brownstein:ISBN9788181287618: Buchanan, B., Gruissem, W and Jones R., by Biochemistry and molecular biology of plants
Plant genome sequencing, Fleury D, Langridge P. 2012.
Plant Biotechnology and Agriculture. Baxevanis, A. D. and Ouellette, B. F. F. (eds). 2001.
Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins, Methods of Biochemical Analysis, vol. 43, 2nd ed., New York: John Wiley and Sons, Inc.
Gene Expression Analysis: Methods and Protocols, Raghavachari N, Garcia-Reyero, N (Eds.) 2018. ISBN 978-1-4939-7834-2,
Springer Transcriptome Data Analysis: Methods and Protocols. Wang Y, Sun, M (Eds.), 2018. ISBN 978-1-4939-7710-9;
Springer Comparative Genomics: Methods and Protocols. Setubal, J C., Stoye, Stadler P (Eds.) ISBN 978-1-4939-7463-4; Springer.
Rosenberg E. 2017. It's in Your DNA. 2017 Recombinant DNA Technology and Genetically Modified Organisms. 2017. Nambisan P. An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology.
He F, Zhang F, Sun W, Ning, and Wang GL. 2018. A Versatile Vector Toolkit for Functional Analysis of Rice Genes 11: 27.doi: 10.1186/s12284-018-0220-7.
Kamburova VS, Nikitina EV, Shermatov SE, Buriev ZT, Kumpatla SP, Emani C and Abdurakhmonov EY. Genome Editing in Plants: An Overview of Tools and Applications International Journal of Agronomy. https://doi.org/10.1155/2017/7315351
Bhardwaj R, Singh R. 2014. Gene Silencing in Emerging Technologies and Management of Crop Stress Tolerance, Volume 1.
Norambuena L, Raikhel NV, Hicks GR. 2009. Chemical genomics approaches in plant biology. Methods Mol Biol. 553: 345-54. doi: 10.1007/978-1-60327-563-7_18.
Dejonghe W and Russinova E. Plant Chemical Genetics: From Phenotype-Based Screens to Synthetic Biology. Plant Physiol. 2017 May; 174(1): 5–20.doi: 10.1104/pp.16.01805
Fiers M, Hoogenboom J, Brunazzi A, Wennekes T, Angenent GC and Immink RGH. 2017. A plant-based chemical genomics screen for the identification of flowering inducers, Plant Methods 201713: 78, https://doi.org/10.1186/s13007-017-0230-2
Gene Overexpression in Cereals for Functional Genomics and Discovery of Useful Genes, Abe K and Ichikawa H. 2016. Front Plant Sci. 7: 1359. doi: 10.3389/fpls.2016.01359 • Gene Overexpression: Uses, Mechanisms, and Interpretation, Prelich G. 2012. 190 no. 3 841- 854; https://doi.org/10.1534/genetics.111.136911
Wusheng Liu C. Neal Stewart Jr Plant synthetic biology https://doi.org/10.1016/ j.tplants.2015.02.004, REVIEW| 20, 5, P309-317, 2015
Plant Synthetic Biology: Quantifying the "Known Unknowns" and Discovering the "Unknown Unknowns" R. Clay Wright, Jennifer Nemhauser, 2019. DOI: https://doi.org/10.1104/ pp.18.01222
Plant synthetic biology for molecular engineering of signalling and development. Nemhauser JL and Torii KU. 2016. Nat Plants 2: 16010.doi: 10.1038/nplants.2016.10

CPH 602	**Signal Perceptions and Transduction and Regulation of Physiological Processes**	**2+0**

Theory

Block 1: Signal Perceptions and Transduction: Regulation of Physiological Processes

Unit 1: Concept of Receptor and Ligands

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

Unit 2: Receptors – Signal Perception and Transfer

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

Unit 3: Hormone Signaling

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

Unit 4: Light Signaling

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

Unit 5: Abiotic Stress Signaling and Nutrient Signalling

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

Unit 6: Signaling Cascade during Developmental Events

Leaf senescence/fruit development and ripening, Tuberization, Sugar signaling. Signaling during seed germination.

Unit 7: Signal Perception and Transduction in Plant Defense Responses

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

Suggested Referances

He, Y., Zhou, J., Shan, L. and Meng, X., 2018. *Plant cell surface receptor-mediated signaling– a common theme amid diversity*. J Cell Sci, 131(2), p.jcs209353.

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Braun, Y., Smirnova, A.V., Weingart, H., Schenk, A. and Ullrich, M.S., 2007. *A temperature sensing histidine kinase—function, genetics, and membrane topology*. Methods In Enzymology: 423: 222-249. Academic Press.

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Snijders, L. and Naguib, M., 2017. *Communication in animal social networks: a missing link. Adv Study Behav*, 49, pp.297-359.

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Eckardt, N.A., 2015. *The plant cell reviews dynamic aspects of plant hormone signaling and crosstalk*.

Chow, B. and McCourt, P., 2006. *Plant hormone receptors: perception is everything. Genes and development*, 2015, 1998-2008.

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S. and Sakr, S., 2014. *Light signaling in bud outgrowth and branching in plants. Plants*, 3(2), 223-250.

Kami, C., Lorrain, S., Hornitschek, P. and Fankhauser, C., 2010. *Light-regulated plant growth and development*. *Current Topics in Developmental Biology* (91: 29-66). Academic Press.

Coureux, P.D. and Genick, U.K., 2007. *Triggering and Monitoring Light Sensing Reactions in Protein Crystals. Methods in Enzymology* (422: 305-337). Academic Press.

Wang, C.S., Hsu, S.W. and Hsu, Y.F., 2013. *New insights into desiccation-associated gene regulation by Lilium longiflorum ASR during pollen maturation and in transgenic Arabidopsis. International Review of Cell and Molecular Biology* (301: pp. 37-94). Academic Press.

Ben-Ari, G. and Lavi, U., 2012. *Marker-assisted selection in plant breeding*. *Plant Biotechnology and Agriculture* (163-184). Academic Press.

Peleg, Z.V.I., Walia, H. and Blumwald, E. 2012. *Integrating genomics and genetics to accelerate development of drought and salinity tolerant crops*. *Plant Biotechnology and Agriculture* 271- 286. Academic Press.

Zhu, J.K., 2016. *Abiotic Stress Signaling and Responses in Plants*. Cell, 167(2): 313-324.

Pandey, G.K., Pandey, A., Prasad, M. and Böhmer, M., 2016. *Abiotic stress signaling in plants: functional genomic intervention. Frontiers in Plant Science*, 7, p.681.

Inaba, T., Yazu, F., Ito-Inaba, Y., Kakizaki, T. and Nakayama, K., 2011. *Retrograde signaling pathway from plastid to nucleus. International Review of Cell and Molecular Biology* (Vol. 290, pp. 167-204). Academic Press.

Khan, M.I.R., Reddy, P.S., Ferrante, A. and Khan, N.A. (eds.). 2019. *Plant Signaling Molecules: Role and Regulation Under Stressful Environments*. Woodhead Publishing.

Sparks, E., Wachsman, G. and Benfey, P.N., 2013. *Spatiotemporal signalling in plant development. Nature Reviews Genetics*. 14(9), p.631.

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Sparks, E., Wachsman, G. and Benfey, P.N. 2013. *Spatiotemporal signalling in plant development. Nature Reviews Genetics* 14(9): p.631.

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plant pathogen: the Dickeya model. Progress in Molecular Biology and Translational Science (142, 51-92). Academic Press.

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Dyakov, Y.T. and Ozeretskovskaya, O.L., 2007. *Vertical pathosystem: avirulence genes and their products. Comprehensive and Molecular Phytopathology* (181-215). Elsevier.

Yamane, H., Konno, K., Sabelis, M., Takabayashi, J., Sassa, T. and Oikawa, H., 2010. *Chemical defence and toxins of plants*.

Vinutha, T., Gupta, O.P., Prashat, G.R., Krishnan, V. and Sharma, P. 2014. *Molecular mechanism of Begomovirus evolution and plant defense response. Plant Virus–Host Interaction* (345-357). Academic Press.

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Signaling and Communication in Plants, ISBN-10: 3540892273Springer; 2009 edition (March 18, 2009)

Sopory SK Oelmuller R, Maheswari SC. 2012. (Ed) *Signal Transduction in Plants: Current Advances*; ISBN-13: 9781461355182

Wang XY, Springer, 2016. *Plant Signalling Networks: Methods and Protocols* ISBN-13: 9781493961696 *Developmental and Cell Biology Series: Hormones, Signals and Target Cells in Plant Development Series* Number 41, Osborne DJ, McManus MT, Cambridge University Press, ISBN-13: 9780521330763

How Plants Communicate Machajewski S. 2018, Rosen Education Service, ISBN-13: 9781538301852

Signal Transduction in Plants Aducci P (Ed), 2011, ISBN-13: 9783034899383

Reactive Oxygen Species: Signaling Between Hierarchical Levels in Plants. Schmitt FJ. Allakhverdiev SI (Eds), 2017, Wiley-Scrivener ISBN-13: 9781119184881

Biocommunication: Sign-Mediated Interactions Between Cells and Organisms Gordon R and Seckbach J (Ed). 2017. World Scientific Publishing Europe Ltd ISBN-13: 9781786340443

Annual Plant Reviews: Intracellular Signaling in Plants Hedden P, Napier R, Yang Z (Ed) 2008, Wiley-Blackwell (an imprint of John Wiley and Sons Ltd) ISBN-13: 9781405160025

CPH 603	Molecular Approaches for Improving Physiological Traits	2+1

Theory

Importance of molecular breeding for complex multi-gene controlled physiological traits and its relevance in augmenting trait based breeding. Physiological traits with relevance to growth, development, abiotic stress tolerance, nutrient acquisition. Approaches for accurate phenotyping of large germplasm accessions and/ or mapping populations. The advantages of "Trait based" breeding approaches. Concept of molecular markers, various

types of dominant and co- dominant marker systems. Relevance and development of mapping populatios and genetic analysis using marker systems. Advantages of association mapping and the concept of linkage, LD decay and population structure. Statistical analysis to assess the variance in phenotypic traits and molecular data. Assessment of genetic parameters such as heritability, genetic advance etc. Strategies for QTL introgression and Marker Assisted Selection (MAS). Map based cloning of novel genes and alleles. Allele mining. Transgenic approach in improving physiological processes- Introduction to G MOs and a pplication i n crop improvement; gene mining, sequence structure & function of candidate genes for various physiological process associated with specific traits (such as stress tolerance) and their potential benefits in transgenic crops. Cloning full- length candidate genes, stress inducible promoters, strategies to clone and characterize and make conatructs for specific crops, gene stacking strategies, tissue specific expression and functional validation of genes. Transformation of crop plants-Agrobacterium and use of other organisms for transformation-particle gun transformation and other methods. Selection of transformants-molecular analysis on the basis of qRT-PCR, Southern, Northern analysis and immunoassays; estimation of copy number. Concept of desirable number of independent events. Evaluation of trangenics on basis of empirical/physiological/biochemical process under specific conditions on the basis of gene function. Generation of T1 populations, event characterization and generation of molecular data as per the regulatory requirements. Issues related to Biosaftey and Registration of Trangenic Agricultural Organisms, methods to detect GMOs from agricultural products.

Practicals

Phenotyping approaches for the different physiological traits. Genotyping options using gene-scan systems. Development of SSR, SNP and SCAR markers, resolution of polymorphism on agarose gels and PAGE, genotyping using a DNA sequencing machine, scoring of gels and assessment of polymorphism, Statistical approaches to assess genetic variability, heritability and other parameters, phylogenic analysis, principal component analysis and construction of dendrograms. Construction of Linkage map, QTL maps, population structure, LD decay etc leading to identification of QTLs, Bioinformatics-sequence analysis, structure analysis, molecular biology-genomic/ plasmid DNA isolation, RNA isolation. Fulllength gene cloning, vector construction with specific promoter, gene stacking & transient assaya. Transformation in model system, Crop transformation-agrobacterium mediated transformation (inplanta & invitro), particle gun transformation, Evaluation of transgenics-semi quantitative RTPCR, southern blot, northern blot, western blot and ELISA, biochemical/ physiological assay based on the function of gene & testing LOD.

Suggested Reference

Physiology and Molecular Biology of stress tolerance in plants by Madhav Rao K.V., Raghavendra, A.S and Janardhan Reddy.K.

CPH 604	Advanced Techniques in Plant Physiology	0+2

Practicals

Recent experimental techniques to study various physiological processes, Photosynthetic gas exchange measurements, light and CO2 response curves-determination of relative limitations to photosynthesis; chlorophyll fluorescence measurements. Estimation of water use efficiency at whole plant and single leaf level. Use of stable isotopes to understand physiological processes. Radio active isotopes in plant biology. Tools and techniques (molecular and biochemical) to study physiological processes and to screen & assess stress responses in plants, such as (a) DNA & RNAisolation, cDNA synthesis & library construction, semiquantitative & quantitative RT-PCR, northern blot, immunoassays; (b) techniques for defined physiological processes. Methods to phenotype germplasm for specific physiological traits. Quantification of mineral nutrients using advanced instruments like AAS& ICP. Techniques in plant transformation & analysis of transgenic plants. Molecular markers-genetic distance and mapping population concept of linkage maps and identification of QTLS. Instrumentation: Acquaintance of the operation of specific instruments important in physiological research like Mass spec., phosphor-imager, DNA sequencer, spectro-fluorometer, oxygen electrode, etc.

Suggested References

Advances in molecular breeding towards draught and self tolerant crops by Ammar E L Akhdar

Plant Pysiology and development . by L.Taiz E Zaiger Plant Pysiology. By Salisborry and Ross

Plant physiology and Development by Lincoln Taiz, edurdo zeiger Ian M Moller and Angus Murphy (Sixth Edition) Plant Physiology by Salisbury F B and Ross C W

CPH 605	Climate Change and Crop Growth	2+0

Theory

History and evidences of climate change and its implications. Effect of climate change on monsoons, hydrological cycle and water availability. Natural and anthropogenic activities and agricultural practices on GHG production, Monitoring of greenhouse gases and their influence on global warming and climate change, Ozone depletion leading to increased ionizing radiations and its implications on crop growth. Long-term and short-term projections of climate change effects on natural vegetations and ecosystems, crop-pest interaction, area shift, food production and supply. Approaches to mitigate climate change through studies on plant responses. Direct and indirect effects of climate change on plant processes phenology, net carbon assimilation, water relations, grain development and carbon assimilation, water relations, grain development and quality, nutrient acquisition and yield. Conventional and biotechnological approaches to improve the crop adaption to climate change. Relevance of "Genome wide mutants" to identify genes/processes for improved adaption to changing environments. International conventions and global initiatives on carbon sequestration, carbon trading.

Suggested References

Global climate change and Agriculture. by Fakhri A Bazzaz
Climate change effects on plant growth ,crop yield and livestock. by R.rotter S E: Springer
Eco physiology of Tropical crops by Advim, T and T.T. Ko210WSK (eds)
Plant growth and climate change etd. By James I.L Morison and Michael
D. Morecroft Climate change impacts on plant Biomass growth by Ali Mohammad

CPH 606	**Molecular Physiology of Mineral Nutrient Acquisition, Transport and Utilization**	**1+1**

Theory

Overview of essential mineral elements, kinetics of nutrients uptake by plants. Biological and chemical reactions influencing nutrient availability near the root system. Nutrient uptake by root cells, long distance transport from vegetative to reproductive organs during reproductive stage of growth and maturity. Molecular mechanism of nitrate, phosphate, potassium and other nutrients. Multiple transporters for a single ion and their functional regulation. Molecular physiology of micronutrient acquisition. Examples of genes encoding mineral ion transporters. Strategies plants adopt to acquire and transport minerals under deficient levels. Physiological and molecular mechanisms underlying differential nutrient efficiency in crop genotypes, examples of phosphorous, iron and zinc efficient crop varieties. Breeding crop varieties for improved nutrient efficiency. Plant responses to mineral toxicity.

Practicals

Physiological and biochemical changes in plants under nutrient sufficiency and deficiency levels. Quantification of pigment levels, enzyme activities and macro molecules. Recent techniques and instruments for determining nutrient levels in plants. Screening techniques for evaluationof nutrient efficiency. Molecular techniques-expression of specific transcripts under nutrient deficient or sufficient conditions.

Suggested References

Diagnosis of mineral disorders in plants by Alan Scaife and Mary Fanna Plant nutritional manual by Benton Jones, J
Plant growth interactions with nutrition and environment by Porter, J.R and Lawlor D W
Principles of plant nutrition by Mengel K and Kirkby E A

FOOD SCIENCE AND NUTRITION

SL NO	COURSE NO	COURSE TITLE	CREDIT HOURS
MINOR COURSES			
01	FSN 601	Advances in Carbohydrates, Proteins and Lipids	1+1
02	FSN 602	Advances in Food Science and Technology	1+1

FSN 601	Advances in Carbohydrates, Proteins and Lipids	1+1

Theory

Carbohydrates, proteins and lipids-their digestion, absorption, metabolism. Inborn errors of metabolism. Metabolic disorders-diabetes, dental caries, obesity, antherosclerosis, hyperlipidemia amd hypertension. Glucose homeostasis determined by insulin/ glycogen ratio; carbohydrates free diet and its metabolic consequences; glycemic index; dietary fiber-its definition, composition, classification, functions and role in various physiological disorders. Classification of protein, new discoveries in prtein and their functions such as protein in Immune system, as lubricants, biological buffers and carriers, evaluation of protein quality: in vitro and in vivo methods, animal and human bioassays: amino acid pool, protein turnover in man with special reference to body size, age and various nutrition and pathogical conditions, regulation of proteins, requirements: novel food source of protein. Effect of insulin, corticosteroids, thyroids, androgen and growth hormone on protein metabolism, inheritable disorders of amino acid metabolism of protein; effect of dietary protein on cardiovascular disease and cholesterol metabolism, adaptation of body to low intake of energy and protein. Estimation of body fat; lipoproteins and hyper lipoproteinemia; hypolipidemic action of PUFA omega-3 fatty acids and oxidation products of cholesterol. Disturbance in lipid metabolism; role of a diet in cardiovascular disorders; high blood cholesterol-causes, prevention and treatment; hypolipidemic action of rice bran, oat, barley and legumes.

Practicals

Assessment of protein quality; project work related to metabolic disorders of proximate principles; blood analysis in relation to NCD (Non Communicable Diseases) and estimation of amylase and protease inhibitors in foods.

Suggested References

Martin Eastwood and E, K, Edinburgh, 2003, Principles of Human Nutrition, Atlantic Publishers and Distributors Pvt. Ltd. New Delhi.

Ashok Kumar Sharma, 2011, Biochemistry of Nutrition, Random Publications, New delhi.

Mahtab S Bamji, Kamala Krishna Swamy, GNV Brahmam, 2016, Text Book of Human Nutrition, Oxford and IBH Publishing Company, Pvt. Ltd., New delhi.

Terene Forro, 2013, Recent Advances in Nutritional Biochemistry and Metabolism,

Random Publications Pvt. Ltd. New Delhi.
Sharma D. C. and Sharma D., 2015, Nutritional Biochemistry, CBS Publishers and Distributors Pvt. Ltd, New Delhi.
Gajalakshmi R., 2012, Nutrition Science, CBS Publishers and Distributors Pvt. Ltd, New delhi.
Sunetra Roday, 2012, Food Science and Nutrition, Oxford University Press, New delhi.
Srilakshmi, B., 2003, Food Science, 3rd Edition, New Age International Publishers, New Delhi.
Sadashivam S and Manickam, A., 2008, Biochemical Methods, New Age International Publishers, New Delhi.
Srilakshmi, B., 2005, Dietetics, 5th Edition, New Age International Publishers, New Delhi.
Ranganna, S, 2001, Handbook of Analysis and Quality Control for Fruit and Vegetable Products, Tata- McGraw Hill, New Delhi.

FSN 602	Advances in Food Science and Technology	1+1

Theory

Recent advances in the field of carbohydrates, lipids, proteins, vitamins and minerals in relation to human nutrition. Nutrogenomics, incorporating genetics into dietary guidance. Recent advances in the field of food analysis and food fortification. Foods of future; special nutrients. Foodprocessing and product development; regulating food processing and preservation through TQM and HACCP. GM foods and their health implications; functional foods and organic foods, impact of WTO in food regulation.

Practicals

Product development and shelf life of nutritionally fortified foods using advanced technologies, field study of food processing and preservation in relation to TQM and HACCP in industry.

Suggested References

Mudambi and Sumati R., 2006, Food Science, New Age International Publishers, New Delhi.
Vikash P, M., sabu Thomas, Laura B, Ituriaga, Pablo Daniel Ribotta, 2013, Advances in Food Science and Technology, Scrivener Publishing LLC, New Delhi.
Suri S and Malhotra, A., 2013, Food Science, Nutrition and Safety, 2013, Pearson Education Pvt. Ltd, New Delhi.
Ranganna, S, 2001, Handbook of Analysis and Quality Control for Fruit and Vegetable Products, Tata- McGraw Hill, New delhi.
Krammer A And Twigg B, A., 1973, Quality Control in Food Industry, AVI Publishers Pvt. Ltd., New delhi.
Srilakshmi, B., 2003, Food Science, 3rd Edition, New Age International Publishers, New Delhi.
Meyer, L.H. 1991, Food Chemistry, Affiliated East-West Press Pvt.Ltd., New Delhi.
Swaminathan, M. 1995, Food Science and Experimental Foods, Ganesh and Co., Madras.
Potter, N. 1987, Food Science, CBS Publishers and Distributors, Delhi.

BIOCHEMISTRY

SL NO	COURSE NO	COURSE TITLE	CREDIT HOURS
MINOR COURSES			
01	BCM 601	Advanced Enzymology	2+0
02	BCM 602	Advanced Molecular Biology	3+0
03	BCM 603	Current Topics in Biochemistry	1+0
04	BCM 604	Advanced Techniques in Biochemistry	0+2

BCM 601	Advanced Enzymology	2+0

Theory

Block 1: Enzymology and Enzyme Engineering

Unit 1: Enzyme catalysis and specificity (7 Lectures)

Theory of enzymatic catalysis, Specificity and editing mechanisms, concept of active site and enzyme substrate complex, active site mapping, factors associated with catalytic efficiency, mechanism of enzyme reactions, detection of intermediates in enzymatic reactions.

Unit 2: Enzyme kinetics (7 Lectures)

Transition state theory, Arrhenius equation, Determination of energy of activation, effect of pH and temperature on enzyme kinetics, pre-steady state and steady state kinetics, single substrate kinetics, allosteric enzymes and mixed inhibition, substrate and product inhibition, numerical exercises.

Unit 3: Enzyme mechanism and regulation (7 Lectures)

Mechanism determination by radioisotope exchange, role of enzymes in regulation of metabolism, bifunctional enzymes, pseudoenzyme and enzyme promiscuity, extremozymes, catalytic nucleic acids (ribozymes, catalytic DNA).

Unit 4: Industrial enzymology (7 Lectures)

Advantages and disadvantages of biocatalysis in technology driven processes, stabilization and regeneration of enzyme systems used in biotechnology, protein engineering of enzymes, creation of chimeric, bifunctional, immobilization of enzymes, semisynthetic enzymes and their use as industrial biocatalysts, and their practical significance, modern information technologies in enzyme engineering.

Suggested Referances

Aehle, W. 2007. *Enzymes in Industry. Production and Application*. (Third, Completely Revised Edition*)*. Wiley-VCH Verlag GmbH & Co. KGaA

Buchholz, K., Bornscheuer, U., Kasche, V. 2012. *Biocatalysts and Enzyme Technology*. UK: Wiley-VCH Verlag GmbH

Fessner, W. and Anthonsen, T. 2009. *Modern Biocatalysis.* Germany: Wiley-VCH Verlag GmbH

Frey, P.A. and Hegeman, A.D. 2007. *Enzymatic Reaction Mechanisms*. Oxford University Press

Young Je Yoo, Yan Feng, Yong-Hwan Kim, Camila Flor J. Yagonia. 2017. *Fundamentals of Enzyme Engineering*. Springer

BCM 602	Advanced Molecular Biology	3+0

Theory

Block 1: Genome Organisation and Manipulation

Unit 1: Concepts of gene and genome

Genes, their relationship with chromosomes, gene number hypothesis; Genome – definition, variation and organization in plants and animals, structure of organelle genomes; concept of epigenome, genome size and genome evolution.

Unit 2: Regulation of gene expression

Prokaryotic and eukaryotic gene regulation, transcriptional and posttranscriptional regulation; regulation at genome level, role of histones, riboswitches.

Unit 3: Techniques in genome analysis

Genome sequencing technologies, Sanger sequencing, next generation sequencing, nanopore sequencing; genome mapping – genetic map construction, physical mapping.

Unit 4: Techniques for gene transfer and genome manipulation

Methods of gene isolation and transfer in plants and animals, agrobacterium mediated and direct transfer of genes in plants and animals; gene silencing technologies: virus induced gene silencing, RNA interface; genome editing -TALENs, CRISPR/cas, ZFN and their application, site directed mutagenesis, Application of genetic engineering in different fields, gene therapy.

Unit 5: Aspects of molecular breeding

Genome browsing, primer design, marker application for breeding, application of MAS in case studies. Bioethics and bio safety guidelines, IPR in recombinant DNA research.

Suggested Referances

Brown, T. A. 2018. Genomes 4. Garland Science

Rippe, K. 2011. Genome Organization and Function in the Cell Nucleus. Wiley VCH Verlag

Primrose, S. B. and Twyman, R.2006. *Principle of Gene Manipulation and Genomics.* 7th edition. Blackwell Publishing

Christopher Howe. 2007. *Gene Cloning and Mani*pulation. 2nd edition. Cambridge University Press

S. Mohan Jain, D S Brar.(eds.). 2009. *Molecular Techniques in Crop Improvement*. 2nd edition. Springer

Boopathi, N. M. 2013. Genetic Mapping and Marker Assisted Selection: Basics, Practiceand Benefits. Springer

Brown, T. A. 2010. *Gene Cloning and DNA Analysis. An Introduction*. Wiley-Blackwell

Singh, K. K. 2015. *Biotechnology and Intellectual Property Rights. Legal and Social Implications.* Springer

BCM 603	Current Topics in Biochemistry	1+0

Theory: Advanced topics related to nutrition and metabolism. Advanced topics related to enzymology and industrial biochemistry. Advanced topics related to molecular biochemistry and immunology. Advanced topics related to metabolic engineering and bioprospecting.

BCM 604	Advanced Techniques in Biochemistry	0+2

Practicals

Isolation and purification of protein from microbial/plant, Animal source. Electrophoretic separation of protein. Determination of molecular weight of protein using PAGEl gel filtration method. Experiments on DNA: isolation, agarose gel electrophoresis and restriction analysis of DNA. Isolation of chloroplast and mitochondria by differential centrifugation and their purification by density gradient centrifugation. isolation and purification of enzymes, isozymic analysis and enzyme immobilization.

HORTICULTURAL STATISTICS

SL NO	COURSE NO	COURSE TITLE	CREDIT HOURS
MINOR COURSES			
01	HST 601	Applied Regression Analysis	2+1
02	HST 602	Multivariate Analysis	2+1
03	HST 603	Advanced Designs of Experiments	2+1
04	HST 604	Regression Analysis	2+1

HST 601	**Applied Regression Analysis**	**2+1**

Theory

Introduction to correlation analysis and its measures; Correlation from grouped data, Biserial correlation, Rank correlation; Testing of population correlation coefficients; Multiple and partial correlation coefficients and their testing. Regression analysis; Method of least squares for curve fitting; Testing of regression coefficients; Multiple and partial regressions. Problem of correlated errors; Auto correlation; Durbin Watson Statistics; Removal of auto correlation by transformation; Analysis of collinear data; Detection and correction of multicollinearity; Examining the multiple regression equation; Concept of weighted least squares; regression equation on grouped data; Various methods of selecting the best regression equation; regression approach applied to analysis of variance in one way classification. Heteroscedastic models, Concept of nonlinear regression and fitting of quadratic, exponential and power curves; Economic and optimal dose, Orthogonal polynomials.

Practicals

Correlation coefficient, various types of correlation coefficients, partial and multiple, testing of hypotheses; Multiple linear regression analysis, partial regression coefficients, testing of hypotheses, residuals and their applications in outlier detection; Handling of correlated errors, multicollinearity; Fitting of quadratic, exponential and power curves, fitting of orthogonal polynomials.

Suggested References

Kleinbaum DG, Kupper LL, Nizam A. 2007. Applied Regression Analysis and Other Multivariable Methods (Duxbury Applied) 4th Ed.

Draper NR and Smith H. 1998. Applied Regression Analysis. 3rd Ed. John Wiley.

Ezekiel M. 1963. Methods of Correlation and Regression Analysis. John Wiley.

Koutsoyiannis A. 1978. Theory of Econometrics. MacMillan.

Kutner MH, Nachtsheim CJ and Neter J. 2004. Applied Linear Regression Models. 4th Ed. With Student CD. McGraw Hill.

HST 602	Multivariate Analysis	2+1

Theory

Concept of random vector, its expectation and Variance-Covariance matrix. Marginal and joint distributions. Conditional distributions and Independence of random vectors. Multinomial distribution. Multivariate Normal distribution, marginal and conditional distributions. Sample mean vector and its distribution. Maximum likelihood estimates of mean vector and dispersion matrix. Tests of hypothesis about mean vector. Wishart distribution and its simple properties. Hotelling's T2 and Mahalanobis D2 statistics. Null distribution of Hotelling's T2. Rao's U statistics and its distribution. Wilks lambdacriterion and statement of its properties. Concepts of discriminant analysis, computation of linear discriminant function, classification between k (e" 2) multivariate normal populations based on LDF and Mahalanobis D2. Principal Component Analysis, factor analysis (simple and multi factor models). Canonical variables and Hierarchical clustering. Single and Complete linkage methods. Path analysis and computation of path coefficients, introduction to multidimensional scaling, some theoretical results, similarities, metric and non metric scaling methods. Concepts of analysis of categorical data.

Practicals

Maximum likelihood estimates of mean-vector and dispersion matrix; Testing of hypothesis on mean vectors of multivariate normal populations; Cluster analysis, Discriminant function, Canonical correlation, Principal component analysis, Factor analysis; Multivariate analysis of variance and covariance, multidimensional scaling.

Suggested References

Abdelmonem A, Virginia AC and Susanne M. 2004. Computer Aided Multivariate Analysis. Chapman & Hall/CRC.

Anderson TW. 1984. An Introduction to Multivariate Statistical Analysis. 2nd Ed. John Wiley. • Arnold SF. 1981. The Theory of Linear Models and Multivariate Analysis. John Wiley.

Giri NC. 1977. Multivariate Statistical Inference. Academic Press.

Johnson RA and Wichern DW. 1988. Applied Multivariate Statistical Analysis. Prentice Hall.

Kshirsagar AM. 1972. Multivariate Analysis. Marcel Dekker.

Muirhead RJ. 1982. Aspects of Multivariate Statistical Theory. John Wiley. Muirhead, RJ. (2005) Aspects of Multivariate Statistical Theory. 2nd Ed. John Wiley.

Rao CR. 1973. Linear Statistical Inference and its Applications. 2nd Ed. John Wiley.

Rencher AC. 2012. Methods of Multivariate Analysis. 3rd Ed. John Wiley.

Srivastava MS and Khatri CG. 1979. An Introduction to Multivariate Statistics. North Holland.

HST 603	Advanced Designs of Experiments	2+1

Theory

Unit I : General properties and analysis of block designs. Balancing criteria. *m*- associate PBIB designs, and their association schemes including lattice designs - properties and construction, Designs for test treatment – control(s) comparisons; Nested block designs, Mating designs.Structurally Incomplete block designs

Unit II : General properties and analysis of two-way heterogeneity designs, Youden type designs, generalized Youden designs, Pseudo Youdendesigns., Designs for two sets of treatments.

Unit III : Balanced factorial experiments - characterization and analysis (symmetrical and asymmetrical factorials). Factorial experiments with extra treatment(s). Orthogonal arrays, Mixed orthogonal arrays, balanced arrays, Fractional replication, Resolution plans, Regular and irregular fractions.

Unit IV : Response surface designs - Symmetrical and asymmetrical factorials, Response optimization and slope estimation, Blocking, Canonical analysis and ridge analysis, CCD, Box-Jenkins, Experiments with mixtures: design and analysis. Experiments with qualitative cum quantitative factors.

Unit V : Optimality criteria and optimality of designs, robustness of designs against loss of data, outliers, etc. Diagnostics in design of experiments.

Practicals

Analysis of block designs, Analysis of Latin square type designs, group divisible designs, triangular designs, lattice designs. Analysis of fractional replications of factorial experiments, analysis of asymmetrical factorials and block designs with factorial structure. Analysis of second order response surface designs.

Suggested Referances

Chakraborti M.C. 1962. Mathematics of Design and Analysis of Experiments. Asia Publ.House.

Dean A.M. and Voss D. 1999. Design and Analysis of Experiments. pringer. Dey A and Mukerjee R. 1999. Fractional Factorial Plans. John Wiley.

Dey A 1986. Theory of Block Designs. Wiley Eastern.

Hall M Jr. 1986. Combinatorial Theory. John Wiley.

Hedayat A.S., Sloane N.J.A. and Stufken J. 1999. Orthogonal Arrays: Theory and Applications. Springer.

John J.A. and Quenouille M.H. 1977. Experiments: Design and Analysis. Charles and Griffin.

Khuri A.I. and Cornell J.A. 1996. Response Surface Designs and Analysis. 2nd Ed. Marcel Dekker.

Montgomery D.C. 2005. Design and Analysis of Experiments. John Wiley.

Ogawa J. 1974. Statistical Theory of the Analysis of Experimental Designs. Marcel Dekker.

Parsad R, Gupta V.K., Batra P.K., Satpati S.K. and Biswas P. 2007. Monograph on a-designs. IASRI, New Delhi.

Raghavarao D. 1971. Construction and Combinatorial Problems in Design of Experiments. John Wiley.

Shah K.R. and Sinha B.K. 1989. Theory of Optimal Designs. Lecture notes in Statistics.

Vol. 54. Springer.
Sharma M.K. 2012. Design and Analysis of Experiments. Kindle Ed. 1st Ed.
Street A.P. and Street D.J. 1987. Combinatorics of Experimental Designs.Oxford Science Publ. Design Resources Server: www.drs.icar.gov.in.

HST 604	Regression Analysis	2+1

Theory

Simple and Multiple linear regressions: Least squares fit, Properties and examples. Polynomial regression: Use of orthogonal polynomials. Assumptions of regression; diagnostics and transformations; Examination of residuals-Studentized residuals, applications of residuals in detecting outliers, identification of influential observations. Lack of fit, Pure error. Testing homoscedasticity and normality of errors, Durbin-Watson test. Use of R2 for examining goodness of fit. Concepts of Least median of squares and its applications; Concept of multicollinearity, Analysis of multiple regression models, estimation and testing of regression parameters, sub- hypothesis testing, restricted estimation. Weighted least squares method: Properties, and examples. Box-Cox family of transformations. Use of dummy variables, Selection of variables: Forward selection, Backward elimination. Stepwise and Stagewise regressions. Introduction to non-linear models, nonlinear estimation: Least squares for nonlinear models.

Practicals

Multiple regression fitting with three and four independent variables; Estimation of residuals, their applications in outlier detection, distribution of residuals; Test of homoscedasticity, and normality, Box-Cox transformation; Restricted estimation of parameters in the model, hypothesis testing, Step wise regression analysis; Least median of squares norm, Orthogonal polynomial fitting.

Suggested References

Barnett V and Lewis T. 1984. Outliers in Statistical Data. John Wiley.
Belsley DA, Kuh E and Welsch RE. 2004. Regression Diagnostics-Identifying Influential Data and Sources of Collinearity. John Wiley.
Chatterjee S and Hadi AS. 2013. Regression Analysis by Example. A John Wiley & sons Publication.
Draper NR and Smith H. 1998. Applied Regression Analysis. 3rd Ed. John Wiley.
McCullagh P and Nelder JA. 1999. Generalized Linear Models. 2nd Ed.Chapman & Hall.
Montgomery DC, Peck EA and Vining GG. 2003. Introduction to Linear Regression Analysis. 3rd Ed. John Wiley.
Rao CR. 1973. Linear Statistical Inference and its Applications. 2ndEd. John Wiley.

SEED SCIENCE AND TECHNOLOGY

SL NO	COURSE NO	COURSE TITLE	CREDIT HOURS
MINOR COURSES			
01	SST 601	Hybrid Seed Production	1+1
02	SST 602	In Situ and Ex Situ Conservation of Germplasm	2+1
03	SST 603	Testing for Genuineness and Purity of Cultivars	1+1
04	SST 604	Seed Storage and Deterioration	2+1
05	SST 605	Advances in Seed Treatment	1+1
06	SST 606	Advances in Seed Science Research	1+1

SST 601	**Hybrid Seed Production**	**1+1**

Theory

Introduction, concepts of hybrid seed production; Heterosis: definition, expression and estimation of hybrid vigour; utilization of heterosis in agricultural, horticultural and other crop plants for crop improvement. Pre-requisites for hybrid seed production; mechanisms and management of pollination in autogamous and allogamous crops; basic principles in hybrid seed production. Techniques of hybrid seed production- emasculation and crossing: use of self-incompatibility, modification of sex; types of male sterility and exploitation in hybrid development and its use in hybrid seed production; development and maintenance of A, B and R lines. Fertility restoration; use of chemical hybridizing agents, problems of non synchrony in flowering of parental lines and methods to overcome; planting ratios and population density in relation to hybrid seed yield; salient features of hybrid seed production of various crops *viz*., rice, sorghum, bajra, maize, sunflower, cotton and other major vegetables.

Practicals

Methods of hybrid seed production in major agricultural and horticultural crops; planting of rowslblocks of parental lines and manipulations for achieving flowering synchrony for production of hybrid seeds, maintenance of A, B and R lines and production of breeder seed; stable diagnostic characteristics of parental lines and their hybrids; genetic purity tests; determination of cost of hybrid seed production of various crops; visitto seed production plots etc.

Reference

AGRAWAL R. L., 1996, Seed Technology, Oxford and IBH Publicity Company, New Delhi.

ARYA, PREM SINGH. 2003. Vegetable seed Production Principles. Kalyani Publishers. Ludhiana.

BHASKARAN, M., BHARATI, A., VANANGAMUDI, K, NATARAJAN, N., NATESAN, P., JERLIN, R. AND PRABHAKAR, K. 2003. Principles of Seed Production. Kaisher Graphics, Coimbatore.

FAGERIA, M. S., ARYA, P. S. AND CHOUDHARY, A. K. 2031. Vegetable Crops -

Breeding and Seed Production. Kalyani Publishers. Ludhiana.
GEETHARANI, P., SWAMINATHAN, V. AND PONNUSWAMI, V., 2007. Seed Technology in Horticultural Crops. NP.H Publications.
GEORGE, R.A.T., 2009, Vegetable Seed Production (3rd edn.). CAB International. McDONALD, M.D. AND COPELAND, C.O., 1998. Seed Production Principles and Practices. CBS Publishers and Distributions, New Delhi.
Vegetable Seed Production Technology. International Book Distributing Co. Lucknow, U.P.
SINGHAL, N. C. 2002. Hybrid Seed Production. Kalyani Publishers, Ludhiana. VANANGAMUDI, K., PRABHU, M., KALAIVANI, S., BHASKERAN, M. AND
MANONMANI, V., 2010. Vegetable Hybrid Seed Production and Management. Agrobios (India).

SST 602	In Situ and Ex Situ Conservation of Germplasm	2+1

Theory

Concept of natural reserves and natural gene banks, In situ conservation of wild species in nature reserves: in situ conservation components, factors influencing conservation value, national plan for in situ conservation; in situ conservation of agro-biodiversity on-farm; scientific basis of in situ conservation on-farm, building on-farm conservation initiatives, implementation of on-farm conservation, management of in situ conserved genetic diversity on-farm, enhancing benefits for farmers from local crop diversity. Ex situ conservation: compgnents, plant genetic resources' conservation in gene banks, national gene banks, 'gene depositories, preservation of genetic materials under natural conditions, perma-frost conservation, guidelines for sending seeds to network of active/ working collections, orthodox, recalcitrant seeds-differences in handling, clonal depositories, genetic stability under long term storage condition. In vitro storage, maintanence of in vitro culture under different conditions, in vitro bank maintenance for temporate and tropical fruit crop species, spices, tubers, bulbous crops, medicinal and endangered plant species, conservation of embryos and ovules, cell/ suspension cultures, protoplastand callus cultures, pollen culture, micropropagation techniques, problems prospects of in vitro gene bank. Cryopreservation-procedure for handling seeds of orthodox and recalcitrants-cryoprotectants, dessication, rapid freezing, slow freezing, vitrification techniques, encapsulation/ dehydration techniques, national facilities, achievements, application of cryopreservation in agriculture, horticulture and forestry crops. Problems and prospects; challenges ahead.

Practicals

In situ conservation of wild species-ease studies at national and Intemationallevels-ex situ techniques for active and long-term conservation of collections-Preparation and handling of materials, packaging, documentation; design of cold storage modules-Conservation protocols for recalcitrant and orthodox seeds; Cytological studies for assessing genetic stability, in vitro cultures-embryo, celVsuspension cultures, pollen cultures, study of cryotank facility and vitrification techniques, visit to NBPGRlNBAGRstudy using fruit crops and other horticultural crops.

Suggested Reference

Approach to Monitor the Viability of Accessions During Storage in Seed Banks. FAO /IBPGR Pl. Genet. Resources News 41-3-18.

Dadlani, S.A., B.P. Singh and R.V. Singh. 1981. System of national and international exchange of germplasm and methods of recording followed at NBPGR. Sci. Monogr. No. 5, NBPGR, New Delhi. pp. 72-87.

DARE/ ICAR Annual report, 2002-2003. Indian Council of Agricultural Research, Department of Agricultural Research and Education Ministry of Agriculture Government of India, New Delhi.

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Frankel, O.H. & Hawkes, J.G., 1975. Crop Genetic Resources for Today and Tomorrow. Cambridge University Press, Cambridge.

Hari Har Ram and Rakesh Yadav, 2007. Genetic Resources and Seed Enterprises Management and Policies, Part-I. New India Publishing Agency, Pitam Pura, New Delhi.(Text book)

J.M.M. Engels, R.K. Arora and L. Guarino. An introduction to plant germplasm exploration and collecting: planning, methods and procedures, follow-up. Keith G. Briggs. Plant Genetic Resources. Management of Agricultural, Forestry and Fisheries Enterprises-Vol.1. Operation Manual for National Clonal Germplasm Repository Processed Report. USDAARS and Orgon State Univ. Oregon, USA.

Paroda, R.S. and Arora, R.K., 1991. Plant Genetic Resources Conservation and Management Concepts and Approaches. International Board for Plant Genetic Resources Regional Office for South and Southeast Asia, New Delhi. (Text book)

Ramanatha Rao V. & Toby Hodgkin, 2002. Genetic diversity and conservation and utilization of plant genetic resources. Plant Cell, Tissue and Organ Culture 68: 1–19.

Simmonds, N.W., 1979. Principles of Crop Improvement Longman. Westwood MN. 1986.

Withers, L.A., 1980. Tissue Culture Storage for Genetic Conservation. IBPGR Tech. Rep. IBPGR, Rome, Italy.

SST 603	Testing for Genuineness and Purity of Cultivars	1+1

Theory

Objective of cultivar purity test, general principles and methods involved. Use and limitations oflaboratory, green house and field plot methods in determination of genuineness of cultivars; a case study in hybrid cotton, reporting of results and inference. Chemical-biochemical tests for species and cultivar purity: phenol test, seed and seedling tests, electrophoretic analysis of seed protein, isozymes etc, use of chromatography for analysis of secondary compounds etc. DNA finger printing (RAPD, SSR, AFLP etc) and their use in varietal purity testing and registration of new varieties. Use of computer-based ml;lchine vision (MVT) for varietal identification and purity testing etc.

Practicals

Chemical and biochemical tests for species and cultivar purity testing: phenol test, seed and seedling tests, electrophoretic analysis of seed protein and isozymes, DNA fingerprinting using PCR techniques, use of chromatography for analysis of secondary compounds.

Suggested Reference

Basra, AS., (Ed.). 1995. Seed Quality: Basic Mechanisms and Agricultural Implications. Food Product Press.

ISTA, 2006. Handbook of Variety Testing. International Seed Testing Association, Switzerland.

KHARE, D. AND BHALE, M.S. 2007. Seed Technology. Scientific Publishers (India).

NABINANANDA GHOSH, 2012. Practical Handbook on Seed Quality Testing Technology. Kalyani Publishers, New Delhi.

UMARANI, R., JERLIN, R., NATARAJAN, N., MASILAMANI, P. AND PONNUSWAMY,

A.S., 2008. Experimental Seed Science and Technology. Agrobios (India).

SST 604	**Seed Storage and Deterioration**	**2+1**

Theory

Life span of seeds of plant species; classification of seeds on the basis of storage behaviour; orthodox and recalcitrant seeds; types of storage; kinds of seed storage (open, bulk, controlled, hermetic, germplasm,cryopreservation); soil-seed bank; terminology; survival curve of seed. Factors affecting seed storability-biotic and abiotic and pre-and postharvest factors affecting seed longevity; the effects of packaging materials, storage fungi and insects, seed treatment and fumigation and storage environmental conditions on seed storability; moisture equilibrium in seeds; hysteresis effect; thumb rules; selection of suitable areas/ places for safe storage; prediction of relative storability and longevity of seed lots, viability equations and nomographs. Concept of seed ageing and deterioration, its causes, symptoms, mechanisms andrelated theories; different changes associated with the loss ofvigour and viability during storage; application of physiological and biochemical techniques for evaluation of seed ageing; genetics of seed viability; effect of seed ageing on crop performance; maintenance of viability and vigour during storage; seed amelioration techniques, mid storage corrections etc. Storage methods- requirement of storage facilities in India; types and storage structures available in the country and their impact on short and long term storage; methods of safe seed storage including eco-friendly techniques used in various group of crops viz. cereals, pulses, oilseeds, fibers, forages and vegetables; operation and management of seed stores; fruit storage; viability loss during transportation and interim storage.

Practicals

To study the effect of storage environmental factors (RR, SMC and temperature) on seed longevity; to study the effect of packaging materials, seed treatment and fumigation on storability; prediction of storability and longevity of seed-lots by using viability equations and nomographs; standardization of accelerated ageing (AA) technique for assessing the seed storability of various crops; estimation of carbohydrates, proteins, fats, enzyme activities, respiration rate and nucleic acids in fresh and aged seeds; use of eco-friendly products and amelioration techniques to enhance quality of stored seeds, visit to seed stores.

Suggested References

Barton LV. 1961. Seed Preservation and Longevity. Burgess Publ.

Basra AS. (Ed.). 1995. Seed Quality: Basic Mechanisms and Agricultural Implications. Food Products Press.

Basra AS. 2006. Handbook of Seed Science and Technology. Food Product Press.

CBS. Justice OL & Bass LN. 1978. Principles and Practices of Seed Storage. Castle House Publ.

Desai BB. 2007. Seed Handbook: Biology, Production, Processing and Storage . Marcel Dekker.

Doijode SD. 2001. Seed Storage of Horticultural Crops.

KHARE, D. P. 1994. Stored Grain Pests and their Management. Kalyani Publishers. Ludhiana.

Kigel J & Galili G. (Eds.). Seed Development and Germination. Marcel Dekker. McDONALD, M.D. AND COPELAND, C.O., 1998. Seed Production Principles and Practices. CBS Publishers and Distributions, New Delhi.

VANANGAMUDI, K. VANANGAMUDI, M., NATARAJAN, K., NATARAJAN, N., RAJA, K., SARVANAN, T. AND DJANAGUIRAMAN, M., 2006. Seed Physiology. Associated Publishing Company, New Delhi.

SST 605	**Advances in Seed Treatment**	**1+1**

Theory

Importance and history of seed treatment-definitions, concepts, classification and methods of eed treatment; Use of different seed treatment materials, seed coating and pelleting, seed colorings, polymer coatings, pesticides and other plant products, bio-inoculants, antibiotics and growth regulators; Physical treatments with abrasives, hot and cold temperature, radio frequency waves, magnetic waves, Micro waves, UV- rays, X-rays and gamma-rays; methods of application and their effects on seed quality-seed germination, seedling vigour, storage, seed health *etc*; Presowing and pre-storage seed treatments-seed priming / invigouration, seed hardening, osmo-conditioning for drought and other abiotic stress conditions, mid-storage corrections etc. Bio efficacy qf seed treatments, seed quarantine regulations; legal terminologies and labeling requirements, biosafety measures *etc*.

Practicals

Use of inert, chemical and non toxic materials of plant origin; seed coating and pelleting and its influence on seed quality; physical, chemical and energy treatments and their influence on seed quality; use ofbiofertilizers, bio-inoculants and bio-pesticides, plant products on germination and viability; use of organic solvents for infusing bio-active chemicals for seed enhancement; seed colouring, seed treatment devices, visit to seed processing plant *etc*.

Suggested References

AGRAWAL R. L., 1996, Seed Technology, Oxford and IBH Publicity Company, New Delhi.

Basra, A.S. (Ed.). 1995. Seed Quality: Basic Mechanisms and Agricultural Implications. Food Product Press, NY.

Basra, A.S. 2006. Handbook of Seed Science and Technology. Food Product. Press, NY Bench, A.L.R. & Sanchez, R,A., 2004. Handbook of Seed Physiology. Food Product Press, NY/ London.

Copland, L.O. & McDonald, M,B. 2004. Seed Science and Technology. Kluwer Acad.

Kalloo, G,, Jain, S,K,, Vari, A,K, & Srivastava, U. 2006. Seed: A Global Perspective. Associated Publishing Company, New Delhi.

K.K. Sharma, U.S. Singh, Pankaj Sharma, Ashish Kumar and Lalan Sharma, 2015. Seed treatments for sustainable agriculture-A review. Journal of Applied and Natural Science 7 (1) : 521 – 539 .

Parvatha Reddy, 2013. Recent advances in crop protection. Springer India.

SST 606	**Advances in Seed Science Research**	**1+1**

Theory

Physiological and molecular aspects of seed development and control of germination and dormancy; gene expression during seed development; desiccation and stress tolerance and conservation; prediction of seed dormancy and longevity using mathematical models; structural changes in membranes of developing seeds during acquisition of desiccation tolerance; dehydration damage and repair in imbibed seeds, seed biotechnology; genetic analysis and QTL mapping of germination traits; seed ageing and ethylene production; recent accomplishments in seed enhancement research and application of nanotechnology. Modem techniques for identification of varieties and hybrids; principles and procedures of electrophoresis, machine vision technique, DNA fmgerprinting and other molecular techniques and their utilization; techniques for improving seed quality; proteomic analysis; seed priming, coating, pelleting and synthetic seeds; GM seeds and their detection, terminator technology (GURT). Detection and identification of seed borne fungi, bacteria, viruses, nematodes and insect pests through advanced techniques like ELISA, PCR based techniques etc.

Practicals

Advanced techniques on seed science research, seed genetic purity testing by various biochemical and molecular markers, Testing of GM seeds. Demonstration of ELISA and PCR techniques. Production of synthetic seeds, seed encapulation. Visit to the R&D units of seed genetic purity testing *etc*.

Suggeste References

Bench, A.L.R. & Sanchez, R.A., 2004. Handbook of Seed Physiology. Food Product Press.

Black, M. & Bewley, J.D., (Eds.). 2000. Seed Technology and its Biological Basis. Sheffield Academic Press. Ny/London.

Nicolas, G., Bradford, K.J., Come, D. & Pritchard, H.W., 2003. The Biology of Seeds, Recent Research Advances. CABI.

SOIL SCIENCE

SL NO	COURSE NO	COURSE TITLE	CREDIT HOURS
		MINOR COURSES	
01	SAC 601	Instrumental Methods of Analysis	1+1
02	SAC 602	Tracer Techniques in Soil and Plant Studies	1+1
03	SAC 603	Remote Sensing and GIS Techniques for Soil and Crop Studies	1+1
04	SAC 604	Physical Chemistry of Soils	1+1
05	SAC 605	Advances in Soil Fertility	1+1
06	SAC 606	Land Use Planning and Watershed Management	1+1
07	SAC 607	Recycling of Organic Resources and Management	1+1

SAC 601	Instrumental Methods of Analysis	1+1

Theory

Theory and application of physicochemical methods used in analytical chemistry. Electrochemical methods-Poten tiometry, pH measurements, potentiometric titration. Conductometry: Conductivity measurements, conductometric titrations. Optical methods-Nature of electromagnetic radiation, interaction ofEMR with matter, Beer-Lamberts Law, spectrometry, nephelometry, turbidometry, flame photometry/ Atomic absorption spectroscopy.

ICP, Mass spectroscopy Principles and applications of X-ray diffraction; Polarimetry-optical activity, dextro and levo rotation and specific rotation. Extraction methods-Partitoning, distribution ratio, single extraction, multiple extraction and counter current extraction. Chromatography-classification of chromatographic techniques, partition chromatography, adsorption chromatography and gas chromatography and high performance liquid chromatography. Use of electron microscopy and its application in agriculture.

Practicals

Electrochemical methods pH meters, potentiometric titrations, conductivity bridge and conductometric t i tration. Optical methodscolorimeters, spectrometers, nepholometers, turbidometers, flame photometers, atomic absorption spectrophotometer, ICPS, Polarimety- Optical activity, dextro and levo rotation, specific rotation. Chromatography-Thin layer chromatography, gas chromatography and HPLC. Electron microscope and use in clay mineralogy. Visit to important local laboratorieslike IISc, IIHR, IRC and ISRO

Suggested References

Hesse P. 971. Textbook of Soil Chemical Analysis. William Clowes & Sons.
Jackson ML. 1967. Soil Chemical Analysis. Prentice Hall of India.
Keith A Smith 1991. Soil Analysis; Modern Instrumental Techniques. Marcel Dekker.

Kenneth Helrich 1990. Official Methods of Analysis. Association of Official Analytical Chemists.

Page AL, Miller RH and Keeney DR. 1982. Methods of Soil Analysis. Part II. SSSA, Madison. • Piper CE. Soil and Plant Analysis. Hans Publ.

Singh D, Chhonkar PK and Pandey RN. 1999. Soil Plant Water Analysis - A Methods Manual. IARI, New Delhi.

Tan KH. 2003. Soil Sampling, Preparation and Analysis. CRC Press/Taylor & Francis.

Tandon HLS. 1993. Methods of Analysis of Soils, Fertilizers and Waters. FDCO, New Delhi.

Vogel AL. 1979. A Textbook of Quantitative Inorganic Analysis. ELBS Longman.

SAC 602	Tracer Techniques in Soil and Plant Studies	1+1

Theory

Atomic structure, radioactivity and units; radioisotopes-properties and decay principles; nature and properties of nuclear radiations; interaction of nuclear radiations with matter. Principles and use of radiation monitoring instruments-proportional, Geiger Muller counter, solid and liquid scintillation counters; neutron moisture meter, mass spectrometry, auto radiography Isotopic dilution techniques used in soil and plant research; use of stable isotopes; principles and use of mass spectrometer; application of isotopes in studies on organic matter, nutrient transformations, rooting pattern and fertilizer use efficiency; carbon dating doses of radiation exposure, radiation safety aspects regulatory aspects, collection, storage and disposal of radioactive wastes.

Practicals

Storage and handling of radioactive materials, Determination of halflife and decay constant, Preparation of soil and plant samples for radioactive measurements, Setting up of experiment on fertilizer use efficiency and cation exchange equilibria using radioisotopes, Determination of A, E and L values of soil using 32P/ 652n, Use of neutron probe for moisture determination, Sample preparation and measurement of 15N enrichment by mass spectrophotometery / emission spectrometry

Suggested References

Stable isotope Techniques in the Study of Biological processes and functioning of Ecosystems by Murray unkovich et al

Use of nuclear techniques in studies of soil plant relationships by Hardarson,

Nitrogen use efficiency in sandy soil using 15 N tracer techniques by Mamdoh Mohamed Hamed Lamy, Lambert

Radioisotopes in Biology (Practical Approach Series) 2 nd Edition by Robert J Slater

Isotopes: Principles and applications 3rd Edition by Gunter Feaure and Teresa M Mensing

SAC 603	Remote Sensing and GIS Techniques for Soil and Crop Studies	1+1

Theory

Introduction and history of remote sensing; sources, propagation of radiations in atmosphere; interactions with matter. Sensor systemscamera, microwave radiometers and scanners; fundamentals of aerial photographs and image processing and interpretations. Application of remote sensing techniques-land use soil surveys, crop stress and yield forecasting, prioritization in watershed and drought management, wasteland identification and management. Significance and sources of the spatial and temporal variability in soils; variability in relation to size of sampling; classical and geo-statistical techniques of evaluation of soil variability. Introduction to GIS and its application for spatial and non-spatial soil and land attributes.

Practicals

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

Suggested References

Nature and properties of soils by Nyle C Brady and Ray R Weil
Remote sensing, Third edition by Robert A Schowengerdt
Remote sensing for geoscientists by Gary L Prost
GIS Applications in Agriculture by Francis J Pierce and David Clay
Application of Remote Sensing in Agriculture by M.D. Steven and J.A. Clark
Remote sensing for agriculture by Prof Ashton Paalman

SAC 604	Physical Chemistry of Soils	1+1

Theory

Colloidal chemistry of inorganic and organic components of soilstheir formation, clay organic interaction. Predictive approaches for cation exchange equilibria-thermodynamics, empirical and diffuse double layer theory (DDL)-relationships among different selectivity coefficients; structure and properties of diffuse double layer. Thermodynamics of nutrient transformations in soils; cationic and anionic exchange and their models, molecular interaction. Adsorption/ desorption isotherms-Langmuir adsorption isotherm, Freundlich adsorption isotherm, normalized exchange isotherm, BET equation; selective and non-selective adsorption of ions on inorganic surfaces and organic surfaces of soil materials (citation of utility in agricultural system). Common solubility equilibria-carbonates, iron oxide and hydroxides, aluminum silicate, aluminum phosphate; electrochemical properties of clays (citation of examples from agricultural use).

Practicals

Extraction of total constituents in soils, Determination of buffering capacity of soil, Determination of cation exchange and anion exchange, Determination of adsorption of isotherms, Determination of quantity and intensity of potassium, Determination of phosphate potentials in soils, Calculation of layer charges.

Suggested References

Soil Physical Chemistry 2nd Edition by Donald Sparks
Soil Chemical analysis Advanced Course by M.L. Jackson
Soil and Water Chemistry An Integrative Course M.E. Essington Essentials of Physical chemistry by Arun Bahl Et al

SAC 605	Advances in Soil Fertility	1+1

Theory

Modern concepts of nutrient availability; soil solution and plant growth; nutrient response functions and availability indices. Nutrient movement in soils; nutrient absorption by plants; mechanistic approach to nutrient supply and uptake by plants; models for transformation and movement of major micronutrients in soils. Chemical equilibria including solid-solution equilbria) involving nutrient ions in soils, particularly in submerged soils. Modern concepts of fertilizer evaluation, nutrient use efficiency and nutrient budgeting. Modern concepts in fertilizer application; soil fertility evaluation techniques; role of soil tests in fertilizer userecommendations; site-specific nutrient management for precision agriculture. Monitoring physical, chemical and biological changes in soils; permanent manurial trials and long-term fertilizer experiments; soil productivity under long-term intensive cropping; direct, residual and cumulative effect of fertilizer use.

Practicals

Soil testing methods for nutrients, F ertliser recommendations for crops by soil testing, STCR approach, DRIS, Biochemical changes in plants under nutrient deficiency levels. Site specific nutrient management. Integrated nutrient management

Suggested References

Soil Fertility Theory and Practice by J.S. Kanwar et al
Soil management of tropical soil fertility by Womer, PL and Swift MJ
Principles of plant nutrition by Mengel K and Kirkby EA
Fundamentals of soil science ISSS, New Delhi Soil chemical analysis by Jackson M L
Fundamental principles of soil science by Dipak sarkar and Abhijit Haldar
Soil fertility by Henry DF Boyd GE 2nd ed
Nature and properties of soils by Nyle C Brady and Ray R. Weil

SAC 606	Land Use Planning and Watershed Management	1+1

Theory

Concept and techniques of land use plannipg; factors governing present land use. Land evaluation methods and soil-site suitability evaluation for different crops; land apability classification and constraints in application. Agro-ecological regions/sub-regions of India and their characteristics in relation to crop production. Water harvesting-concept, significance, types, methodology; use of harvested water in agriculture to increase water productivity. Watershed development / management-concept, objectives, characterization, planning, execution, community participation and evaluation; rehabilitation of watershed; PRA; developing economically and ecologically sustainable agro-forestry systems for watershed; case studies.

Practicals

Determination of different soil erodibility indices-suspension percentage, dispersion ratio, erosion ratio, clay ratio, clay/ moisture equivalent ratio, perc'olation ratio, raindrop erodibility index, Land capability classification, Fertility capability classification, Irrigability classification, Visits to a watersheds

Suggested References

Remote Sensing and GIS Approach for prioritization of watershed by Sharma Shailesh Kumar et al

Watershed management planning using remote sensing and GIS by Rajnikumar patel

Integrated land use planning for sustainable Agriculture and Rural Development by M.C. Rao et al

Developments in soil classification, land use planning and policy implication by Shahid shabbier A et al

SAC 607	Recycling of Organic Resources and Management	1+1

Theory

Organic resources-definition, classification, characteristics, composition, criteria for recycling of organic resources, Major degradation pathways of organic resources. Soil organic matter pools, mineralisation. Composting-history, definition, objectives, essentials, technologies, types, advantages and limitations. Biochemical changes during decomposition, relationship between ligninun, cellulose, poly phenols and other constituents, factors influencing compo sting, quality standard of compost. Agro-industrial organic resources-characteristics and bioconversion technologies. Crop residue management, Vermitechnology, Biofertilizersinfluence on soil and plant growth. Sewage treatment, sludge chemistry, uses and after effects, Integrate nutrient management, organic farming, biodynamic farming-salient features and utility.

Practicals

Recent technique in compost making and enriched compost. Visit to biogas and sewage and compost plants-acquaint with techniques adopted. Collection of raw materials, biogas spent slurry, sludge and compost. Manurial constituent analysis of different organic resources.

Suggested References

Soil Enzymology in the recycling of Organic wastes and environmental Restoration by Carmen Trasar Cepeda et al
Integrated Waste Management Volume II by Sunil Kumar
Organic waste recycling, 2nd Edition by Chongrak Polprasert
Management of organic waste by Sunil Kumar and Ajay Bharati

REGISTRAR
UHS, BAGALKOT.