

**PG Degree Programme Syllabus as per BSMA, ICAR
M.Sc. (Agri.) Agronomy**



**M.S. Swaminathan School of Agriculture
Centurion University of Technology and Management
Alluri Nagar, P.O. - R Sitapur, Via- Uppalada, Paralakhemundi
Dist: Gajapati – 761211
Odisha, India
2022**

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Centurion
UNIVERSITY
*Shaping Lives...
Empowering Communities...*

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Preamble

Agronomy is a discipline which deals with various processes such as cultivation, inter-culture, management of field through various measures like weed management, soil fertility development, proper use of water resources and so on. Agronomy has a major component of agro ecology which includes several activities that affect the environment and human population. An Agronomist remains in the centre of effort to work with issues related to environmental and ecological concerns and to increase the production of food, feed, fuels and fibre for growing population in world. Agronomist today is involved with many issues including producing food, creating healthier food, managing environmental impacts, creating energy from plants and after all food and nutritional security. Research activities in Agronomy focus on system analysis and simulation modeling of environmental and management impacts on agricultural production which are key to the sustainability of agricultural production system. Hence, it is very much essential to revise the course curriculum of Agronomy so that students even teachers may be well acquainted with the present concept of development of the discipline. This will help bringing competency in students along with confidence so as to develop himself/herself for tackling field problems and management of land. The existing M.Sc. (Agri.) courses of Agronomy have been modified taking into account of present day need by incorporating the necessary and important topics in the respective courses.

Minor changes have been made in most of the existing courses. As a part of the course curriculum, M. Sc. (Agri.) Agronomy was restructured to equip students to tackle emerging issues by inclusion of one new course on “Conservation agriculture”. It was proposed by some members to include new courses like Experimental technique in Agronomy. But finally, it was decided that these courses should be offered by the core departments such as Department of Seed Technology, Department of Statistics and Department of Soil Science, respectively. There are few courses in the existing syllabus which are not offered by many universities. Hence these courses are merged and thereby reduced the number of courses to limit choice so that complete knowledge of the subject can be given to the students. In all the courses, the practical aspects are strengthened.

Topics such as automated irrigation systems, value chain addition/post-harvest processing, variable rate application, precision farming, protected agriculture, soil less farming, farm mechanization of practical operations, practical applications of advanced tools for big data analysis and interpretation, artificial intelligence, drones etc. are included in the revised syllabus so that students can show competency at national and international level.

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Framework of the courses

The following nomenclature and Credit Hrs. need to be followed while providing the syllabus for all the disciplines

Courses	M.Sc. (Agri.) Credits
Major courses	20
Minor courses	08
Supporting courses	06
Common courses	05
Seminar	01
Thesis	30
Total	70

M.Sc. (Agri.) Agronomy

Couse Code	Course Title	Credit	Page No.
Major Courses			
AGRO 0501*	Modern Concepts in Crop Production	3+0	3
AGRO 0502*	Principles and practices of Soil Fertility and Nutrient Management	2+1	4
AGRO 0503*	Principles and Practices of Weed Management	2+1	5
AGRO 0504*	Principles and Practices of Water Management	2+1	6
AGRO 0505	Conservation Agriculture	1+1	9
AGRO 0506	Agronomy of Major Cereals and Pulses	2+1	10
AGRO 0507	Agronomy of Oilseed, Fibre and Sugar crops	2+1	12
AGRO 0508	Agronomy of Medicinal, Aromatic & Underutilized Crops	2+1	13
AGRO 0509	Agronomy of Fodder and Forage crops	2+1	14
AGRO 0510	Agrostology and Agro- Forestry	2+1	16
AGRO 0511	Cropping System and Sustainable Agriculture	2+0	17
AGRO 0512	Dryland Farming and Watershed Management	2+1	18

AGRO 0513	Principles and Practices of Organic Farming	2+1	20
AGRO 0550	Master's Seminar	1+0	-
AGRO 0560	Master's Research	30	-
Minor Courses			
SOIL 0511	Management of Problem Soils and Waters	2+1	22
SOIL 0505	Soil Erosion and Conservation	2+1	23
SOIL 0602	Advances in Soil Fertility	2+0	24
PGPP 0501	Principles of Plant Physiology I: Plant Water Relations and Mineral Nutrition	2+1	25
PGPP 0505	Hormonal Regulation of Plant Growth and Development	2+1	28
PGPP 0507	Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modeling	2+0	31
Supporting Courses			
STAT 0502	Statistical Methods for Applied Sciences	3+1	34
STAT 0511	Experimental Designs	2+1	35
STAT 0512	Basic Sampling Techniques	2+1	37
STAT 0522	Data Analysis Using Statistical Packages	2+1	38
Common Courses			
PGSS 0501	Library and Information Services	0+1	40
PGSS 0502	Technical Writing and Communication Skills	0+1	40
PGSS 0503	Intellectual Property and its Management in Agriculture	1+0	41
PGSS 0504	Basic Concepts in Laboratory Techniques	0+1	42
PGSS 0505	Agricultural Research, Research Ethics and Rural Development Programmes	1+0	43

***Indicates core course which is compulsory course for M Sc.(Agri.)**

M.Sc. (Agri.) Agronomy Syllabus

MAJOR COURSES

Course Code: AGRO 0501

Credit Hours: 3+0

Course Title: Modern Concepts in Crop Production

Objective: To teach the basic concepts of soil management and crop production.

Course Outcome: Basic knowledge on soil management and crop production

Theory

UNIT I

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

UNIT II

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

UNIT III

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

UNIT IV

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

UNIT V

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and class discussion

Suggested Reading

Balasubramaniyan P & Palaniappan SP. 2001. Principles and Practices of Agronomy. Agrobios.

Fageria NK. 1992. Maximizing Crop Yields. Marcel Dekker.

Havlin JL, Beaton JD, Tisdale SL & Nelson WL. 2006. Soil Fertility and Fertilizers. 7th Ed. Prentice Hall.

Paroda R.S. 2003. Sustaining our Food Security. Konark Publ. Reddy SR. 2000. Principles of Crop Production. Kalyani Publ.
Sankaran S & Mudaliar TVS. 1997. Principles of Agronomy. The Bangalore Printing & Publ.
Singh SS. 2006. Principles and Practices of Agronomy. Kalyani.
Alvin, P.T. and Kozłowski, T.T. (ed.) 1976. Ecophysiology of Tropical Crops. Academia Pul., New York.
Gardner, P.P., Pearce, G.R. and Mitchell, R. L. 1985. Physiology of Crop Plants. Scientific Pub. Jodhpur.
Lal, R. 1989. Conservation tillage for sustainable agriculture: Tropics versus Temperate Environments. Advances in Agronomy 42: 85-197.
Wilsie, C.P. 1961. Crop Adaptation and Distribution. Euresia Pub., New Delhi.

Course Code: AGRO 0502

Credit hour: 2+1

Course Title: Principle and Practices of Soil Fertility and Nutrient Management

Objective: To impart knowledge of fertilizers and manures as sources of plant nutrients and apprise about the integrated approach of plant nutrition and sustainability of soil fertility.

Course Outcome: Basic knowledge on soil fertility and management

Theory

UNIT I

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

UNIT II

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

UNIT III

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

UNIT IV

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

UNIT V

Time and methods of manures and fertilizers application; foliar application and its concept; relative performance of organic and inorganic nutrients; economics of fertilizer use; integrated nutrient management; use of vermincompost and residue wastes in crops.

Practical

- Determination of soil pH
- Determination of soil soil EC
- Determination of soil organic C
- Determination of available N in soil
- Determination of available P in soil
- Determination of available K in soil
- Determination of available S in soil
- Determination of total N in soil
- Determination of total N in plant
- Determination of total P in plant
- Determination of total K in plant
- Determination of total S in plant
- Computation of optimum and economic yield

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and class discussion

Suggested Reading

Brady NC & Weil R.R 2002. The Nature and Properties of Soils. 13th Ed. Pearson Edu.
Fageria NK, Baligar VC & Jones CA. 1991. Growth and Mineral Nutrition of Field Crops. Marcel Dekker.

Havlin JL, Beaton JD, Tisdale SL & Nelson WL. 2006. Soil Fertility and Fertilizers. 7th Ed. Prentice Hall.

Prasad R & Power JF. 1997. Soil Fertility Management for Sustainable Agriculture. CRC Press.

Yawalkar KS, Agrawal JP & Bokde S. 2000. Manures and Fertilizers. Agri-Horti Publ.

Course Code: AGRO 0503

Credit Hours: 2+1

Course Title: Principles and Practices of Weed Management

Objective: To familiarize the students about the weeds, herbicides and methods of weed control.

Course Outcome: Basic knowledge on weed identification and control for crop production

Theory

UNIT I

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

UNIT II

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

UNIT III

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

UNIT IV

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

UNIT V

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

Practical

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, field visit to identify weeds.

Suggested Reading

Zimdahl R. L., (ed). 2018. Integrated Weed Management for Sustainable Agriculture, B.D. Sci. Pub

Jugulan, Mithila, (ed). 2017. Biology, Physiology and Molecular Biology of Weeds. CRC Press

T. K. Das. 2008. Weed Science: Basics and Applications, Jain Brothers (New Delhi) Chauhan Bhagirath and Mahajan Gulshan. 2014. Recent Advances in Weed Management. Springer.

Fennimore, Steven A and Bell, Carl. 2014. Principles of Weed Control, 4th Ed, California Weed Sci. Soc.

Monaco, T. J. Weller, S. C. & Ashton, F. M. 2014. Weed Science Principles and Practices, Wiley

Gupta, O. P. 2007. Weed Management: Principles and Practices, 2nd Ed. Walia, U.S. 2006. Weed Management, Kalyani.

Böger, Peter, Wakabayashi, Ko, Hirai, Kenji (Eds.). 2002. Herbicide Classes in Development. Mode of Action, Targets, Genetic Engineering, Chemistry. Springer.

Powles, S. B. and Shaner, D. L. 2001. Herbicide Resistance and World Grains, CRC Press.

Course Code: AGRO 0504

Credit Hour: 2+1

Course Title: Principles and Practices of Water Management

Objective: To teach the principles of water management and practices to enhance the water productivity

Course Outcome: Basic knowledge on water management for optimization of crop yield.

Theory

UNIT I

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

UNIT II

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

UNIT III

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

UNIT IV

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

UNIT V

Excess of soil water and plant growth; water management in problem soils, drainage

requirement of crops and methods of field drainage, their layout and spacing; rain water management and its utilization for crop production.

UNIT VI

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

UNIT VII

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

UNIT VIII

Hydroponics

UNIT IX

Water management of crops under climate change scenario.

Practical

- Determination of Field capacity by field method
- Determination of Permanent Wilting Point by sunflower pot culture technique
- Determination of Field capacity and Permanent Wilting Point by Pressure Plate Apparatus
- Determination of Hygroscopic Coefficient
- Determination of maximum water holding capacity of soil
- Measurement of matric potential using gauge and mercury type tensiometer
- Determination of soil-moisture characteristics curves
- Determination of saturated hydraulic conductivity by constant and falling head method
- Determination of hydraulic conductivity of saturated soil below the water table by auger hole method
- Measurement of soil water diffusivity
- Estimation of unsaturated hydraulic conductivity
- Estimation of upward flux of water using tensiometer and from depth ground water table
- Determination of irrigation requirement of crops (calculations)
- Determination of effective rainfall (calculations)
- Determination of ET of crops by soil moisture depletion method
- Determination of water requirements of crops
- Measurement of irrigation water by volume and velocity-area method
- Measurement of irrigation water by measuring devices and calculation of irrigation efficiency
- Determination of infiltration rate by double ring infiltrometer

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and field visit

Suggested Reading

- Majumdar D.K. 2014. Irrigation Water Management: Principles and Practice.PHL Learning private publishers
- Mukund Joshi.2013.A Text Book of Irrigation and Water Management Hardcover , Kalyani publishers
- Lenka D. 1999. Irrigation and Drainage. Kalyani.
- Michael AM. 1978. Irrigation: Theory and Practice. Vikas Publ.
- Paliwal KV. 1972. Irrigation with Saline Water. IARI Monograph, New Delhi. Panda SC. 2003. Principles and Practices of Water Management. Agrobios.
- Prihar SS & Sandhu BS. 1987. Irrigation of Food Crops - Principles and Practices. ICAR.
- Reddy SR. 2000. Principles of Crop Production. Kalyani.
- Singh Pratap&Maliwal PL. 2005. Technologies for Food Security and Sustainable Agriculture. Agrotech Publ.

Course Code: AGRO 0505

Credit Hour: 1+1

Course Title: Conservation Agriculture

Objective: To impart knowledge of conservation of agriculture for economic development.

Course Outcome: Experience on the knowledge of various types of conservation of agriculture.

Theory

UNIT I

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

UNIT II

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

UNIT III

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

UNIT IV

CA in agroforestry systems, rainfed /dryland regions

UNIT V

Economic considerations in CA, adoption and constraints, CA: The future of agriculture

Practical

- Study of long-term experiments on CA
- Evaluation of soil health parameters
- Estimation of c- sequestration
- Machinery calibration for sowing different crops
- Weed seed bank estimation under CA
- Energy requirements, economic analysis of CA.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

Suggested Reading

Muhammad, F. and Kamdambot, H.M.S. (2014). Conservation Agriculture.

Publisher: Springer Cham Heidelberg, New York Dordrecht London. Doi: 10.1007/978-3-319-11620

Bisht, J.K., Meena, V.S., Mishra, P.K. and Pattanayak, A. (2016). Conservation Agriculture-An approach to combat climate change in Indian Himalaya. Publisher: Springer Nature. Doi: 10/1007/978-981-10-2558-7.

Gracia-Torres, L., Benites, J., Martinez-Vilela, A. and Holgado-Cabera, A. (2003). Conservation Agriculture- Environment Farmers experiences, innovations Socio- economic policy.

Arakeri HR & Roy D. 1984. Principles of Soil Conservation and Water Management. Oxford & IBH.

Dhruvanarayana VV. 1993. Soil and Water Conservation Research in India. ICAR.

FAO. 2004. Soil and Water Conservation in Semi-Arid Areas. Soils Bull., Paper 57.

Yellamanda Reddy T & Sankara Reddy GH. 1992. Principles of Agronomy. Kalyani.

Course Code: AGRO 0506

Credit Hour: 2+1

Course Title: Agronomy of Major Cereals and Pulses

Objective: To impart knowledge of crop husbandry of cereals and pulse crops.

Course Outcome: Basic knowledge on cereals and pulse growing in the country.

Theory

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

UNIT I

Rabi cereals

UNIT II

Kharif cereals

UNIT III

Rabi pulses

UNIT IV

Kharif pulses

Practical

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and class discussion

Suggested Reading

- Das NR. 2007. Introduction to Crops of India. Scientific Publ.
- Hunsgi G & Krishna KR. 1998. Science of Field Crop Production. Oxford & IBH. Jeswani LM & Baldev B. 1997. Advances in Pulse Production Technology. ICAR. Khare D & Bhale MS. 2000. Seed Technology. Scientific Publ.
- Kumar Ranjeet & Singh NP. 2003. Maize Production in India: Golden Grain in Transition. IARI, New Delhi.
- Pal M, Deka J & Rai RK. 1996. Fundamentals of Cereal Crop Production. Tata McGraw Hill.
- Prasad, Rajendra. 2002. Text Book of Field Crop Production. ICAR.
- Singh C, Singh P & Singh R. 2003. Modern Techniques of Raising Field Crops. Oxford & IBH.
- Singh, SS. 1998. Crop Management. Kalyani. Yadav DS. 1992. Pulse Crops. Kalyani.

Course Code: AGRO 0507

Credit Hour: 2+1

Course Title: Agronomy of Oilseed, Fibre and Sugar Crops

Objective: To teach the crop husbandry of oilseed, fiber and sugar crops

Course Outcome: Basic knowledge on production of oil seed , sugar and fibre crops.

Theory

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

UNIT I

Rabi oilseeds – Rapeseed and mustard, Linseed and Niger

UNIT II

Kharif oilseeds - Groundnut, Sesame, Castor, Sunflower, Soybean and Safflower

UNIT III

Fiber crops - Cotton, Jute, Ramie and Mesta.

UNIT IV

Sugar crops – Sugar-beet and Sugarcane.

Practical

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and class discussion

Suggested Reading

Das NR. 2007. Introduction to Crops of India. Scientific Publ. Das PC. 1997. Oilseed Crops

of India. Kalyani.

Lakshmikantam N. 1983. Technology in Sugarcane Growing. 2nd Ed. Oxford & IBH. Prasad, Rajendra. 2002. Text Book of Field Crop Production. ICAR.

Singh C, Singh P & Singh R. 2003. Modern Techniques of Raising FieldCrops. Oxford & IBH.

Singh SS. 1998. Crop Management. Kalyani.

Course Code: AGRO 0508

Credit hour: 2+1

Course Title: Agronomy of Medicinal, Aromatic and Under Utilized Crops

Objectives: To acquaint students about different medicinal, aromatic and underutilized field crops, their package of practices and processing.

Course Outcome: acquainted with various MAP and their commercial base for developing entrepreneurship.

Theory

UNIT I

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

UNIT II

Climate and soil requirements; cultural practices; yield and important constituents of medicinal plants (Mulhati, Isabgol, Rauwolfia, Poppy, Aloe vera, Satavar, Stevia, Safed Musli, Kalmegh, Asaphoetida, Nuxvomica, Rosadle etc).

UNIT III

Climate and soil requirements; cultural practices; yield and important constituents of aromatic plants (Citronella, Palmarosa, Mentha, Basil, Lemon grass, Rose, Patchouli, Geranium).

UNIT IV

Climate and soil requirements; cultural practices; yield of under-utilized crops (Rice bean, Lathyrus, Sesbania, Clusterbean, French bean, Fenugreek, Grain Amaranth, Coffee, Tea and Tobacco).

UNIT V

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

Practical

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

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and field visit

Suggested Reading

- Chadha KL & Gupta R. 1995. Advances in Horticulture. Vol. II. Medicinal and Aromatic Plants. Malhotra Publ.
- Das NR. 2007. Introduction to Crops of India. Scientific Publ.
- Handa SS. 1984. Cultivation and Utilization of Medicinal Plants. RRL, CSIR, Jammu.
- iv. Hussain A. 1984. Essential Oil Plants and their Cultivation. CIMAP, Lucknow.
- Hussain A. 1993. Medicinal Plants and their Cultivation. CIMAP, Lucknow.
- ICAR 2006. Hand Book of Agriculture. ICAR, New Delhi.
- Kumar N, Khader Md. Abdul, Rangaswami JBM & Irulappan 1997. Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants. Oxford & IBH.
- Prajapati ND, Purohit SS, Sharma AK & Kumar T. 2003. A Hand Book of Medicinal Plants: A Complete Source Book. Agrobios.
- Sharma R. 2004. Agro-Techniques of Medicinal Plants. Daya Publ. House.

Course Code: AGRO 0509

Credit Hours: 2+1

Course Title: Agronomy of Fodder and Forage Crops

Objective: To teach the crop husbandry of different forage and fodder crops along with their processing.

Course Outcome: acquainted with various fodder and forage crops and their commercial base for developing entrepreneurship.

Theory

UNIT I

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

UNIT II

Adaptation, distribution, varietal improvement, agro-techniques and quality aspects including anti-quality factors of important forage crops/grasses like Napier grass, Panicum, Lasiurus, Cenchrus etc.

UNIT III

Year-round fodder production and management, preservation and utilization of forage and pasture crops.

UNIT IV

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

UNIT V

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

Practical

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and field visit

Suggested Reading

Chatterjee BN. 1989. Forage Crop Production - Principles and Practices. Oxford & IBH.

Das NR. 2007. Introduction to Crops of India. Scientific Publ. Narayanan TR & Dabardghao PM. 1972. Forage Crops of India. ICAR.

Singh P & Srivastava AK. 1990. Forage Production Technology. IGFRI, Jhansi.

Singh C, Singh P & Singh R. 2003. Modern Techniques of Raising Field Crops. Oxford & IBH.

Tejwani KG. 1994. Agroforestry in India. Oxford & IBH.

Course Code: AGRO 0510

Credit Hours: 2+1

Course Title: Agrostology and Agro-Forestry

Objective: To teach crop husbandry of different forage, fodder and agroforestry crops/trees along with their processing

Course Outcome: Basic knowledge on agro forestry, forage crops and their utility

Theory

UNIT I

Agrostology: definition and importance; principles of grassland ecology: grassland ecology –

community, climax, dominant species, succession, biotype, ecological status of grasslands in India, grass cover of India; problems and management of grasslands.

UNIT II

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

UNIT III

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

UNIT IV

Crop production technology in agro-forestry and agrostology system; silvipastoral system: meaning and importance for wasteland development; selection of species, planting methods and problems of seed germination in agro-forestry systems; irrigation and manuring in agro-forestry systems, associative influence in relation to above ground and underground interferences; lopping and coppicing in agro-forestry systems; social acceptability and economic viability, nutritive value of trees; tender operation; desirable tree characteristics.

Practical

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and field visit

Suggested Reading

:Chatterjee BN & Das PK. 1989. Forage Crop Production. Principles and Practices. Oxford & IBH.

Dabadghao PM & Shankaranarayan KA. 1973. The Grass Cover in India. ICAR. Dwivedi AP. 1992. Agroforestry- Principles and Practices. Oxford & IBH.

Indian Society of Agronomy. 1989. Agroforestry System in India. Research and

Development, New Delhi.

Narayan TR & Dabadghao PM. 1972. Forage Crop of India. ICAR, New Delhi.

Course Code: AGRO 0511

Credit Hours: 2+0

Course Title: Cropping Systems and Sustainable Agriculture

Objective: To acquaint the students about prevailing cropping systems in the country and practices to improve their productivity.

Course Outcome: Basic knowledge on cropping system for sustainable agriculture.

Theory

UNIT I

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

UNIT II

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

UNIT III

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

UNIT IV

Crop diversification for sustainability; role of organic matter in maintenance of soil fertility; crop residue management; fertilizer use efficiency and concept of fertilizer use in intensive cropping system. Advanced nutritional tools for big data analysis and interpretation.

UNIT V

Plant ideotypes for drylands; plant growth regulators and their role in sustainability.

UNIT VI

Artificial Intelligence- Concept and application.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment.

Suggested Reading

Panda S. C. (2017). Cropping systems and sustainable agriculture. Agrobios (India) Panda S. C. (2018) Cropping and farming systems. Agrobios.

Palaniappan SP & Sivaraman K. 1996. Cropping Systems in the Tropics; Principles and Management. New Age.

Panda SC. 2003. Cropping and Farming Systems. Agrobios. Reddy SR. 2000. Principles of Crop Production. Kalyani.

Sankaran S & Mudaliar TVS. 1997. Principles of Agronomy. The Bangalore Printing & Publ. Co.

Tisdale SL, Nelson WL, Beaton JD & Havlin JL. 1997. Soil Fertility and Fertilizers. Prentice Hall.

Course Code: AGRO 0512

Credit Hours: 2+1

Course Title: Dryland Farming and Watershed Management

Objective: To teach the basic concepts and practices of dry land farming and soil moisture conservation.

Course Outcome: Basic knowledge on dry land farming and soil moisture conservation.

Theory

UNIT I

Definition, concept and characteristics of dry land farming; dry land versus rainfed farming; significance and dimensions of dry land farming in Indian agriculture.

UNIT II

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

UNIT III

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

UNIT IV

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

UNIT V

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

Practical

- Method of Seed Priming
- Determination of moisture content of germination of important dryland crops

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment.

Suggested Reading

- Reddy T.Y. 2018. Dryland Agriculture Principles & Practices, Kalyani publishers
- Dhopte AM. 2002. Agrotechnology for Dryland Farming. Scientific Publ.
- Dhruv Narayan VV. 2002. Soil and Water Conservation Research in India. ICAR.
- Gupta US. (Ed.). 1995. Production and Improvements of Crops for Drylands. Oxford & IBH.
- Katyal JC & Farrington J. 1995. Research for Rainfed Farming. CRIDA.
- Rao SC & Ryan J. 2007. Challenges and Strategies of Dryland Agriculture. Scientific Publ.
- Singh P & Maliwal PL. 2005. Technologies for Food Security and Sustainable Agriculture. Agrotech Publ. Company.
- Singh RP. 1988. Improved Agronomic Practices for Dryland Crops. CRIDA.
- Singh RP. 2005. Sustainable Development of Dryland Agriculture in India. Scientific Publ.
- Singh SD. 1998. Arid Land Irrigation and Ecological Management. Scientific Publ.

Course Code: AGRO 0513

Credit Hours: 2+1

Course Title: Principles and Practices of Organic Farming

Objective: To study the principles and practices of organic farming for sustainable crop production.

Course Outcome: Basic knowledge on organic farming for sustainable agriculture and development of entrepreneurship on organic inputs.

Theory

UNIT I

Organic farming - concept and definition, its relevance to India and global agriculture and

future prospects; principles of organic agriculture; organics and farming standards; organic farming and sustainable agriculture; selection and conversion of land, soil and water management - land use, conservation tillage; shelter zones, hedges, pasture management, agro-forestry.

UNIT II

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

UNIT III

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

UNIT IV

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

UNIT V

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

Practical

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment, exposure visit

Suggested Reading

Joshi, Mukund 2016. New Vistas of Organic Farming. Scientific Publishers

Ananthakrishnan TN. (Ed.). 1992. Emerging Trends in Biological Control of Phytophagous Insects. Oxford & IBH.

Gaur AC. 1982. A Manual of Rural Composting, FAO/UNDP Regional Project Document, FAO.

Lampin N. 1990. Organic Farming. Press Books, Ipswich, UK.

Palaniappan SP & Anandurai K. 1999. Organic Farming – Theory and Practice.

Scientific Publ.

Rao BV Venkata. 1995. Small Farmer Focused Integrated Rural Development: Socio-economic Environment and Legal Perspective:

Publ.3, ParisaraprajnaParishtana, Bangalore.

Reddy MV. (Ed.). 1995. Soil Organisms and Litter Decomposition in the Tropics. Oxford & IBH.

Sharma A. 2002. Hand Book of Organic Farming. Agrobios.

Singh SP. (Ed.) 1994. Technology for Production of Natural Enemies. PDDB, Bangalore.

Subba Rao NS. 2002. Soil Microbiology. Oxford & IBH.

Trivedi RN.1993. A Text Book of Environmental Sciences, Anmol Publ.

Veeresh GK, Shivashankar K &Suiglachar MA. 1997. Organic Farming and Sustainable Agriculture. Association for Promotion of Organic Farming, Bangalore.

WHO. 1990. Public Health Impact of Pesticides Used in Agriculture.WHO.

Woolmer PL & Swift MJ. 1994. The Biological Management of Tropical Soil Fertility. TSBF & Wiley.

MINOR COURSES

Course Code: SOIL 0511

Credit Hours: 2+1

Course Title: Management of Problem Soils and Water

Objective: To educate students about basic concepts of problem soil sand. Brackish water ,and their management .Attention will be on Management of problem soils and safe use of brackish water in Relation to crop production.

Course Outcome: Experience on solving field problem of problem soil and waters.

Theory

UNIT I

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

UNIT II

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

UNIT III

Management of salt-affected soils; salt tolerance of crops mechanism and ratings; Salt stress meaning and its effect on crop Growth, monitoring of soil salinity in the field; management principles For sandy, clayey, red lateritic and dry lands oils.

UNIT IV

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

UNIT V

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

UNIT VI

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

Practical

- Characterization of acid, acid sulfate, sal t-affected and calcareous soil
- Determination of cations (Na⁺,K⁺,Ca⁺⁺and Mg⁺⁺)in ground water and soil samples
- Determination of anions (Cl⁻,SO₄⁻⁻,CO₃⁻⁻and HCO₃⁻)in ground

- Waters and soil samples, Lime and gypsum requirements of acid and sodic soils.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

Suggested Reading

Bear FE. 1964. Chemistry of the Soil. Oxford & IBH.

Jurinak JJ. 1978. Salt-affected Soils. Department of Soil Science & Biometeorology. Utah State Univ.

USDA Handbook No. 60. 1954. Diagnosis and improvement of Saline and Alkali Soils. Oxford & IBH.

Course Code: SOIL 0505

Course Credits: 2+1

Course Title: Soil Erosion and Conservation

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

Theory

UNIT I

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

UNIT II

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

UNIT III

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

UNIT IV

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

UNIT V

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

UNIT V

Watershed management - concept, objectives and approach; water harvesting and recycling;

flood control in watershed management; socioeconomic aspects of watershed management; case studies in respect to monitoring and evaluation of watersheds; use of remote sensing in assessment and planning of watersheds.

Practical

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

Suggested Reading

Biswas TD & Narayanasamy G. (Eds.) 1996. *Soil Management in Relation to Land Degradation and Environment*. Bull. Indian Society of Soil Science No. 17.

Doran JW & Jones AJ. 1996. *Methods of Assessing Soil Quality*. Soil Science Society of America, Spl Publ. No. 49, Madison, USA.

Gurmal Singh, Venkataramanan C, Sastry G & Joshi BP. 1990. *Manual of Soil and Water Conservation Practices*. Oxford & IBH.

Hudson N. 1995. *Soil Conservation*. Iowa State Univ. Press. Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.

Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

Course Code: SOIL 0602

Credit Hours: 2+0

Course Title: Advances in Soil Fertility

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

Theory

UNIT I

Modern concepts of nutrient availability; soil solution and plant growth; nutrient response functions and availability indices.

UNIT II

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

UNIT III

Chemical equilibria (including solid-solution equilibria) involving nutrients in soils, particularly in submerged soils.

UNIT IV

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

UNIT V

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

UNIT VI

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

Suggested Reading

Barber SA. 1995. *Soil Nutrient Bioavailability*. John Wiley & Sons.

Barker V Allen & Pilbeam David J. 2007. *Handbook of Plant Nutrition*. CRC / Taylor & Francis.

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

Cooke GW. 1979. *The Control of Soil Fertility*. Crossby Lockwood & Sons.

Epstein E. 1987. *Mineral Nutrition of Plants - Principles and Perspectives*. International Potash Institute, Switzerland.

Kabata-Pendias Alina 2001. *Trace Elements in Soils and Plants*. CRC/ Taylor & Francis.

Kannaiyan S, Kumar K & Govindarajan K. 2004. *Biofertilizers Technology*. Scientific Publ.

Mortvedt JJ, Shuman LM, Cox FR & Welch RM. (Eds.). 1991.

Micronutrients in Agriculture. 2nd Ed. Soil Science Society of America, Madison.

Prasad R & Power JF. 1997. *Soil Fertility Management for Sustainable Agriculture*. CRC Press.

Stevenson FJ & Cole MA. 1999. *Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulphur, Micronutrients*. John Wiley & Sons.

Stevenson FJ. (Ed.). 1982. *Nitrogen in Agricultural Soils*. Soil Science Society of America, Madison.

Tisdale SL, Nelson WL, Beaton JD & Havlin JL. 1990. *Soil Fertility and Fertilizers*. 5th Ed. Macmillan Publ.

Wild A. (Ed.). 1988. *Russell's Soil Conditions and Plant Growth*. 11th Ed. Longman.

Course Code: PGPP 0501

Credit Hours: 2+1

Course Title: Principles of Plant Physiology I - Plant Water Relations and Mineral Nutrition

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

Theory

A. Plant Water Relations

1. Soil and Plant Water Relations
2. Water Absorption and Translocation
3. Transpiration and Evaporative Cooling
4. Water Productivity and Water Use Efficiency
5. Moisture Stress and Plant Growth

B. Mineral Nutrition

1. Nutrient Elements and their Importance
2. Nutrient Acquisition
3. Concept of Foliar Nutrition

Block A: Plant Water Relations

UNIT I

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

Unit II

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

UNIT III

Transpiration and Evaporative Cooling Evaporation and transpiration; relevance of transpiration; factors regulating transpiration; Measurement of transpiration; approaches to minimize evaporation and transpiration; Concept of CCATD and its relevance. Energy balance: Solar energy input and output at crop canopy level. Stomata- its structure, functions and distribution; Molecular mechanisms of stomatal opening and closing; Concept of guard cell turgidity; role of K and other osmolytes; role of ABA in stomatal closure; Guard cells response to environmental signals; Signaling cascade associated with stomatal opening and closure. Antitranspirants and their relevance in agriculture.

UNIT IV

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

UNIT V

Moisture Stress and Plant Growth Physiology of water stress in plants; Effect of moisture stress

at molecular, cellular, organ and plant level. Drought indices and drought tolerance strategies. Drought tolerance traits.

Block B: Mineral Nutrition

UNIT I

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

UNIT II

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

UNIT III

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

Practical

- Standard solutions and preparation of different forms of solutions
- Studies on the basic properties of water
- Demonstration of surface tension of water and other solvents
- Measurement of plant water status: Relative water content and rate of water loss
- Determination of water potential through tissue volume and Chardakov's test
- Determination of water potential using pressure bomb, osmometer, psychrometer
- Determination of soil moisture content and soil water potential
- Use of soil moisture probes and soil moisture sensors
- Measurement of transpiration rate in plants; use of porometry
- Measurement of CCATD and its relevance
- Demonstration and use of anti-transpirants to reduce transpiration
- Influence of potassium and ABA on stomatal opening and closing respectively
- Deficiency and toxicity symptoms of nutrients
- Effect of water stress on plant growth and development

Suggested Reading

Vilalta JM and Forner NG. 2017. Water potential regulation, stomatal behaviour and hydraulic transport under drought: deconstructing the iso/anisohydric concept Plant, Cell and Environment 40, 962–976

Mangrich AS, Cardoso EMC, Doumer ME, Romão LPC, Vidal M, Rigol A, Novotny EH. Improving the Water Holding Capacity of Soils of Northeast Brazil by Biochar Augmentation. Chapter 16, pp 339–354.

McElrone AJ, Choat B, Gambetta GA and Brodersen CR. 2013. Water Uptake and Transport in Vascular Plants. Nature Education Knowledge 4(5): 6

Hodson RC and J Acuff. 2006. Water transport in plants: anatomy and physiology. Pages 163-183, Tested Studies for Laboratory Teaching, Volume 27 (M.A. O'Donnell, Editor). Proceedings of the 27th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 383 pages.

Chater CCC, Caine RS, Fleming AJ, Gray JE. 2017. Plant Physiology, 174 (2) 624-638; DOI: 10.1104/pp.17.00183

Dietrich P, Sanders D, Hedrich R. 2001. The role of ion channels in light dependent stomatal opening, Journal of Experimental Botany, Volume 52, Issue 363, Pages 1959–1967, <https://doi.org/10.1093/jexbot/52.363.1959>

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

Seyed Yahya Salehi-Lisar Hamideh Bakhshayeshan-Agdam, (2016). Drought Stress in Plants: Causes, Consequences, and Tolerance. Drought Stress Tolerance in Plants, Vol 1 pp 1-16

Pandey R. 2015. Mineral Nutrition of Plants. 10.1007/978-81-322-2286-6_20.

Barker AV and DJ Pilbeam. 2015. Handbook of Plant Nutrition, Second Edition. Books in Soils, Plants, and the Environment Series, the 2nd Edition, CRC Press.

Vatansever R, Ozyigit II and Filiz E. 2017. Essential and beneficial trace elements in plants, and their transport in roots: a review. Applied biochemistry and biotechnology 181(1), 464- 482.

Tahat MM and Sijam K. 2012. Arbuscularmycorrhizal fungi and plant root exudates biocommunications in the rhizosphere. African Journal of Microbiology Research, 6(46), 7295-7301.

Rajasekar MD, Nandhini DU and Suganthi S. 2017. Supplementation of Mineral Nutrients through Foliar Spray – A Review. Int.J.Curr.Microbiol.App.Sci. 6(3): 2504-2513.<https://doi.org/10.20546/ijcmas.2017.603.283>

Tarek A and Hassan ER. 2017. Foliar application: from plant nutrition to biofortification. Environment, Biodiversity and Soil Security. 10.21608/jenvbs.2017.1089.1006.

Course Code: PGPP 0505

Credit Hours: 2+1

Course Title: Hormonal Regulation of Plant Growth and Development

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

Theory

A. Plant Growth and Development:

1. Introduction to Plant Hormones Hormonal Regulation
2. Plant Hormones - Discovery and Metabolism
3. Physiological Role of Hormones in Plant Growth and Development
4. Endogenous Growth Substances other than Hormones

5. Hormone Signaling
6. Key Genes Regulating Hormone Levels and Functions
7. Crosstalk of Hormones in Regulation of Plant Growth and Development Processes
8. Practical Utility of Growth Regulators in Agriculture and Horticulture

Block 1: Plant Growth and Development: Hormonal Regulation

UNIT I

Introduction to Plant Hormones Growth, differentiation and development regulated by plant growth substances, Definition and classification of growth regulating substances: Classical hormones, Definition and classification of growth regulating substances: Endogenous growth substances other than hormones, Synthetic chemicals.

UNIT II

Plant Hormones – Discovery and Metabolism Discovery, biosynthetic pathways and metabolism of Auxin, Discovery, biosynthetic pathways and metabolism of Gibberellins, Discovery, biosynthetic pathways and metabolism of Cytokinins, Discovery, biosynthetic pathways and metabolism of Abscisic acid, Discovery, biosynthetic pathways and metabolism of Ethylene, Discovery, biosynthetic pathways and metabolism of Brassinosteroids, Discovery, biosynthetic pathways and metabolism of Strigolactones.

UNIT III

Physiological Role of Hormones in Plant Growth and Development Physiological functions of Auxin and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Gibberellins and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Cytokinins and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Abscisic acid and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Ethylene and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Brassinosteroids and Strigolactones and use of mutants and transgenic plants in elucidating the physiological functions, Discovery, biosynthetic pathways metabolism and physiological roles of Salicylic acid and Peptide hormones.

UNIT IV

Endogenous Growth Substances other than Hormones Discovery, biosynthetic pathways metabolism and physiological role of Polyamines and Karrikins, Discovery, biosynthetic pathways metabolism and physiological roles of Jasmonates and Tricentanol, Discovery, biosynthetic pathways metabolism and physiological roles of systemins Concept of death hormone, Recent developments in elucidating responses of Salicylic acid, Peptide hormones and Polyamines at physiological and molecular level, Recent developments in elucidating responses of Jasmonates, Systemins, Karrikins and Tricentanol at physiological and molecular level.

UNIT V

Hormone Signaling Hormone signal perception, transduction - Receptors, components and mechanism (Auxin, Gibberellin, Cytokinin, ABA and Salicylic acid), Hormone signal perception, transduction - Receptors, components and mechanism (Ethylene, Jasmonate,

Brassinosteroids and strigolactones), Advances in elucidating the structure and function of receptors and signaling components of important hormones.

UNIT VI

Key Genes Regulating Hormone Levels and Functions Genomics approaches to regulate hormone metabolism and its effect on plant growth and development – case studies.

UNIT VII

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

UNIT VIII

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

Practical

- Extraction of Auxins from plant tissue
- Separation and detection of Auxins by GC / GC-MS / HPLC / Immunological technique
- Bioassay of auxin- effect on rooting of cuttings
- Extraction of abscisic acid (ABA) from plant tissue
- Separation and detection of ABA by HPLC/Immunological technique
- ABA bioassays- effect on stomatal movement
- Preparation of samples for ethylene estimation in plant tissue
- Estimation of ethylene in plant tissues using gas chromatography
- Ethylene bioassays, estimation using physico-chemical techniques- effect on breaking dormancy in sunflower and groundnut
- Extraction of Gibberellins from plant tissue- GC / GC-MS / HPLC
- Separation and detection of GA by GC / GC-MS / HPLC/Immunological technique
- GA bioassays- effect on germination of dormant seeds
- Cytokinin- extraction from plant tissue
- Separation and detection of cytokinin by GC / GC-MS / HPLC
- Cytokinin bioassays- effect on apical dominance and senescence / stay green

Suggested Reading

Davies P.J. 2004, Plant Hormones: Biosynthesis, Signal Transduction and Action, 2nd Edition. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Hedden, P. and Thomas, S.J. 2006. Plant Hormone Signalling, Blackwell Publishing Ltd., Oxford, UK.

Osborne, D.J. and McManus, M.T. 2005. Hormones, Signals and Target Cells in Plant Development. Cambridge University Press, New York, USA.

Tucker, G.A. and Roberts, J.A. 2000. Plant Hormone Protocols. Humana Press-Springer Science, New York, USA.

Buchanan B B, Gruissem W and Jones R L. Biochemistry and Molecular biology of Plants, 2nd Edition

Lincoln Taiz and Eduardo Zeiger. Plant Physiology and Development, 6th Edition.

Teaching Tools in Plant Biology, The American Society of Plant Biologists

The Arabidopsis Book (<http://www.arabidopsisbook.org/>).

Course Code: PGPP 0507

Credit Hours: 2+1

Course Title: Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modelling

Objective: Agronomic inputs and environmental factors enhance crop growth by improving photosynthetic processes and photosynthetic partitioning.

Theory

Block 1: Photosynthetic Processes

UNIT I

Canopy Architecture and Energy Utilization

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

UNIT I

Photochemical Processes

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

UNIT III

Biochemical Processes

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

UNIT IV

Product Synthesis and Translocation

Triose phosphate utilization and regulation of Calvin cycle mechanisms, Product synthesis and partitioning between starch and sucrose, Concepts of end-product inhibition or Pi-

regeneration limitation, Phloem transport and factors that regulate phloem loading and unloading.

UNIT V

Growth and Yield forming Mechanisms

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

Block 2: Yield Improvement and Modelling

UNIT I

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

UNIT II

Fundamentals of Dynamic Simulation Models Collection of crop specific genetic coefficient, Crop, soil and historic weather data

UNIT III: Description of Well-established Yield Models Application and limitations of modeling, Yield prediction models such as APSYM, Peanut Grow etc, Machine learning approaches and IoT for making informed on- farm decisions.

UNIT IV

Examples of Robust Models Extensively Used Duncan's yield prediction model, Passioura's model for growth maximising.

Practical

- Plant sampling for leaf area and biomass estimation; analysis of growth and yield parameters – LAD, NAR, CGR, LAI, LAR, SLA partitioning efficiency, HI.
- Measurement of light interception, light extinction coefficient, energy utilization efficiency based energy intercepted, and realized.
- Gas exchange: principles and uses to assess variations in CO₂ and water vapour transfer, determination of A/gs and intrinsic WUE
- Quantification of chlorophyll content by various methods: colorimetric and SPAD meter. The concept of SLN

- Chlorophyll fluorescence and quenching coefficients
- Theoretical aspects of carbon isotope fractional and its use in determining WUE
- Quantification of RUBISCO content by ELISA (if possible)
- Determination of RUBISCO activity and activation state using radioactive CO-2
- CO₂ and light response curves and computation of carboxylation efficiency, quantum efficiency, relative limitations of photosynthesis at single leaf level.
- Adoption of crop models: Growth and yield prediction by Duncan's and Passioura's models

Teaching methods/activities: Lecture, Assignment (Reading/Writing), Student presentation, Practical

Suggested Reading

Goyne, P.J., Milroy, S.P., Lilley, J.M., and Hare, J.M. (1993). Radiation interception, radiation use efficiency and growth of barley cultivars. *Australian Journal of Agricultural Research*, 44(6), 1351-1366. <https://www.sciencedirect.com/topics/chemistry/photosynthetic-pigment>.

Frank, H.A., Young, A., Britton, G., and Cogdell, R.J. (Eds.). (2006). *The photochemistry of carotenoids* (Vol. 8). Springer Science and Business Media.

Ruban, A.V. (2016). Nonphotochemical chlorophyll fluorescence quenching: mechanism and effectiveness in protecting plants from photodamage. *Plant Physiology*, 170(4), 1903-1916.

MaXwell, K., and Johnson, G.N. (2000). Chlorophyll fluorescence—a practical guide. *Journal of Experimental Botany*, 51(345), 659-668. https://www.researchgate.net/publication/38051229,_The_photochemical_reaction_in_photosynthesis.

Wang, Y., Stessman, D.J., and Spalding, M.H. (2015). The CO₂ concentrating mechanism and photosynthetic carbon assimilation in limiting CO₂: how *Chlamydomonas* works against the gradient. *The Plant Journal*, 82(3), 429-448.

Dietz, K.J., and Pfannschmidt, T. (2011). Novel regulators in photosynthetic redox control of plant metabolism and gene expression. *Plant Physiology*, 155(4), 1477-1485.

SUPPORTING COURSES

Course Code: STAT 0502

Credit Hours: 3+1

Course Title: Statistical Methods for Applied Sciences

Objective: This course is meant for students who do not have sufficient background of Statistical Methods. The students would be exposed to concepts of statistical methods and statistical inference that would help them in understanding the importance of statistics. It would also help them in understanding the concepts involved in data presentation, analysis and interpretation. The students would get an exposure to presentation of data, probability distributions, parameter estimation, tests of significance, regression and multivariate analytical techniques.

Theory

UNIT I

Classification, tabulation and graphical representation of data. Box-plot, Descriptive statistics. Exploratory data analysis; Theory of probability. Random variable and mathematical expectation.

UNIT II

Discrete and continuous probability distributions: Binomial, Poisson, Negative Binomial, Normal distribution, Beta and Gamma distributions and their applications. Concept of sampling distribution: chi-square, t and F distributions. Tests of significance based on Normal, chi-square, t and F distributions. Large sample theory.

UNIT III

Introduction to theory of estimation and confidence-intervals. Correlation and regression. Simple and multiple linear regression model, estimation of parameters, predicted values and residuals, correlation, partial correlation coefficient, multiple correlation coefficient, rank correlation, test of significance of correlation coefficient and regression coefficients. Coefficient of determination. Polynomial regression models and their fitting. Probit regression analysis by least squares and maximum likelihood methods, confidence interval for sensitivity; Testing for heterogeneity.

UNIT IV

Non-parametric tests - sign, Wilcoxon, Mann-Whitney U-test, Wald Wolfowitz run test, Run test for the randomness of a sequence. Median test, Kruskal- Wallis test, Friedman two-way ANOVA by ranks. Kendall's coefficient of concordance.

UNIT V

Introduction to multivariate analytical tools- Hotelling's T² Tests of hypothesis about the mean vector of a multinormal population. Classificatory problems and discriminant function, D²-statistic and its applications; Cluster analysis, principal component analysis, canonical

correlations and Factor analysis.

Practical

- Exploratory data analysis
- Box-Cox plots; Fitting of distributions Binomial, Poisson, Negative Binomial, Normal
- Large sample tests, testing of hypothesis based on exact sampling distributions ~ chi square, t and F
- Confidence interval estimation and point estimation of parameters of binomial, Poisson and Normal distribution
- Correlation and regression analysis, fitting of orthogonal polynomial regression
- Applications of dimensionality reduction and discriminant function analysis Nonparametric tests.

Suggested Reading

Anderson TW. 1958. An Introduction to Multivariate Statistical

Analysis. John Wiley. Dillon WR & Goldstein M. 1984. Multivariate Analysis - Methods and Applications. John Wiley.

Goon AM, Gupta MK & Dasgupta B. 1977. An Outline of Statistical Theory. Vol. I. The World Press.

Goon AM, Gupta MK & Dasgupta B. 1983. Fundamentals of Statistics. Vol. I. The World Press.

Hoel PG. 1971. Introduction to Mathematical Statistics. John Wiley. 304

Hogg RV & Craig TT. 1978. Introduction to Mathematical Statistics. Macmillan.

Morrison DF. 1976. Multivariate Statistical Methods. McGraw Hill. Siegel S, Johan N &

Casellan Jr. 1956. Non-parametric Tests for Behavior Sciences. John Wiley. Learning Statistics: <http://freestatistics.altervista.org/en/learning.php>. Electronic

Statistics Text Book: <http://www.statsoft.com/textbook/stathome.html>.

Course Code: STAT 0511

Credit Hours: 2+1

Course Title: Experimental Designs

Objective: This course is meant for students of agricultural and animal sciences other than Statistics. Designing an experiment is an integrated component of research in almost all sciences. The students would be exposed to concepts of Design of Experiments so as to enable them to understand the concepts involved in planning, designing their experiments and analysis of experimental data

Theory

UNIT I

Need for designing of experiments, characteristics of a good design. Basic principles of designs- randomization, replication and local control.

UNIT II

Uniformity trials, size and shape of plots and blocks; Analysis of variance; Completely randomized design, randomized block design and Latin square design.

UNIT III

Factorial experiments, (symmetrical as well as asymmetrical) orthogonality and partitioning of degrees of freedom, Confounding in symmetrical factorial experiments, Factorial experiments with control treatment.

UNIT IV

Split plot and strip plot designs; Analysis of covariance and missing plot techniques in randomized block and Latin square designs; Transformations, crossover designs, balanced incomplete block design, resolvable designs and their applications ~ Lattice design, alpha design - concepts, randomization procedure, analysis and interpretation of results. Response surfaces. Experiments with mixtures.

UNIT V

Bioassays- direct and indirect, indirect assays based on quantal dose response, parallel line and slope ratio assays potency estimation

.Practical

- Uniformity trial data analysis, formation of plots and blocks, Fairfield Smith Law
- Analysis of data obtained from CRD, RBD, LSD
- Analysis of factorial experiments without and with confounding
- Analysis with missing data
- Split plot and strip plot designs
- Transformation of data
- Analysis of resolvable designs
- Fitting of response surfaces

Suggested Reading

Cochran WG & Cox GM. 1957. Experimental Designs. 2nd Ed. John Wiley.

Dean AM & Voss D. 1999. Design and Analysis of Experiments. Springer.

Federer WT. 1985. Experimental Designs. MacMillan.

Fisher RA. 1953. Design and Analysis of Experiments. Oliver & Boyd.

Nigam AK & Gupta VK. 1979. Handbook on Analysis of Agricultural Experiments. IASRI Publ.

Pearce SC. 1983. The Agricultural Field Experiment: A Statistical Examination of Theory and Practice. John Wiley. Design Resources Server: www.iasri.res.in/design

Course Code: STAT 0512

Credit Hours: 2+1

Course Title: Basic Sampling Techniques

Objective: This course is meant for students of agricultural and animal sciences other than Statistics. The students would be exposed to elementary sampling techniques. It would help them in understanding the concepts involved in planning and designing their surveys, presentation of survey data analysis of survey data and presentation of results. This course would be especially important to the students of social sciences.

Theory

UNIT I

Concept of sampling, sample survey vs complete enumeration, planning of sample survey, sampling from a finite population.

UNIT II

Simple random sampling with and without replacement, sampling for proportion, determination of sample size, inverse sampling, Stratified sampling.

UNIT III

Cluster sampling, Multi-stage sampling, systematic sampling; Introduction to PPSampling,

UNIT IV

Use of auxiliary information at estimation, Ratio product and regression estimators.
Double Sampling, sampling and non-sampling errors.

Practical

- Random sampling ~ use of random number tables, concepts of unbiasedness, variance, etc.
- Simple random sampling, determination of sample size, inverse sampling, stratified sampling, cluster sampling and systematic sampling
- Estimation using ratio and regression estimators
- Estimation using multistage design, double sampling

Suggested Reading

Cochran WG. 1977. Sampling Techniques. John Wiley.

Murthy MN. 1977. Sampling Theory and Methods. 2nd Ed. Statistical Publ. Soc., Calcutta.

Singh D, Singh P and Kumar P. 1982. Handbook on Sampling Methods. IASRI Publ.

Sukhatme PV, Sukhatme BV, Sukhatme S and Asok C. 1984. Sampling Theory of Surveys with Applications. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.

Cochran WG. 2007. Sampling Techniques, 3rd Edition. John Wiley & Sons Publication

Course Code: STAT 0522

Credit Hour: 2+1

Course Title: Data Analysis using Statistical Packages

Objective: This course is meant for exposing the students in the usage of various statistical packages for analysis of data. It would provide the students an hands on experience in the analysis of their research data. This course is useful to all disciplines.

Theory

UNIT I

Use of Software packages for: Summarization and tabulation of data; Descriptive statistics; Graphical representation of data, Exploratory data analysis.

UNIT II

Fitting and testing the goodness of fit of discrete and continuous probability distributions; Testing of hypothesis based on large sample test statistics; Testing of hypothesis using chi-square, t and F statistics.

UNIT III

Concept of analysis of variance and covariance of data for single factor, multi- factor, one-way and multi-classified experiments, contrast analysis, multiple comparisons, Analyzing crossed and nested classified designs.

UNIT IV

Analysis of mixed models; Estimation of variance components; Testing the significance of contrasts; Correlation and regression including multiple regression.

UNIT V

Discriminant function; Factor analysis; Principal component analysis; Analysis of time series data, Fitting of non-linear models; Time series data; Spatial analysis; Neural networks.

Practical

- Use of software packages for summarization and tabulation of data
- obtaining descriptive statistics, graphical representation of data
- Robust Estimation, Testing linearity and normality assumption
- Estimation of trimmed means etc.
- Cross tabulation of data including its statistics cell is play and table format and means for different sub-classifications
- Fitting and testing the goodness of fit of probability distributions Testing the hypothesis for one sample t -test, two sample t -test, paired t test, t for large samples - Chi-squares test, F test, One way analysis of variance , contrast and its testing, pairwise comparisons; Multiway classified analysis of variance - cross-classification, nested classification, factorial set up, fixed effect models, random effect models, mixed effect models, estimation of variance components
- Generalized linear models - analysis of unbalanced data sets, testing and significance of

contrasts, Estimation of variance components in unbalanced data sets – maximum likelihood, ANOVA, REML, MINQUE

- Bivariate and partial correlation, Distances - to obtain a distance matrix, dissimilarity measures, similarity measures; Linear regression, Multiple regression, Regression plots, Variable selection, Regression statistics, Fitting of growth models - curve estimation models, examination of residuals; Discriminant analysis - fitting of discriminant functions, identification of important variables, Factor analysis. Principal component analysis-obtaining principal component, spectral composition; Analysis of time series data - fitting of ARIMA models, working out moving averages. Spatial analysis; Neural networks.

Suggested Reading

- Anderson CW & Loynes RM. 1987. *The Teaching of Practical Statistics*. John Wiley.
- Atkinson AC. 1985. *Plots Transformations and Regression*. Oxford University Press.
- Chambers JM, Cleveland WS, Kleiner B & Tukey PA. 1983. *Graphical Methods for Data Analysis*. Wadsworth, Belmont, California.
- Chatfield C & Collins AJ. 1980. *Introduction to Multivariate Analysis*. Chapman & Hall. 311
- Chatfield C. 1983. *Statistics for Technology*. 3rd Ed. Chapman & Hall.
- Chatfield C. 1995. *Problem Solving: A Statistician's Guide*. Chapman & Hall.
- Cleveland WS. 1985. *The Elements of Graphing Data*. Wadsworth, Belmont, California.
- Ehrenberg ASC. 1982. *A Primer in Data Reduction*. John Wiley.
- Erickson BH & Nosanchuk TA. 1992. *Understanding Data*. 2nd Ed. Open University Press, Milton Keynes.
- Snell EJ & Simpson HR. 1991. *Applied Statistics: A Handbook of GENSTAT Analyses*. Chapman & Hall.
- Sprent P. 1993. *Applied Non-parametric Statistical Methods*. 2nd Ed. Chapman & Hall.
- Tufte ER. 1983. *The Visual Display of Quantitative Information*. Graphics Press, Cheshire, Conn.
- Velleman PF & Hoaglin DC. 1981. *Application, Basics and Computing of Exploratory Data Analysis*. Duxbury Press.
- Weisberg S. 1985. *Applied Linear Regression*. John Wiley.
- Wetherill GB. 1982. *Elementary Statistical Methods*. Chapman & Hall.
- Wetherill GB. 1986. *Regression Analysis with Applications*. Chapman & Hall.
- Learning Statistics: <http://freestatistics.altervista.org/en/learning.php>. Free Statistical Softwares: <http://freestatistics.altervista.org/en/stat.php>.
- Statistics Glossary http://www.cas.lancs.ac.uk/glossary_v1.1/main.html. Course on Experimental design: <http://www.stat.sc.edu/~grego/courses/stat706/.Design>
- Resources Server: www.iasri.res.in/design. Analysis of Data: Design Resources Server. <http://www.iasri.res.in/design/Analysis%20of%20data/Analysis%20of%20Data.html>.

COMMON COURSES

The following courses (one credit each) will be offered to all students undergoing Master's degree programme.

Course Code: PGSS 0501

Credit Hours: 0+1

Course Title: Library and Information Services

Objective: To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines etc.) of information search.

Practical

- Introduction to library and its services
- Role of libraries in education, research and technology transfer
- Classification systems and organization of library
- Sources of information- Primary Sources, Secondary Sources and Tertiary Sources
- Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.)
- Tracing information from reference sources; Literature survey
- Citation techniques/Preparation of bibliography
- Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services
- Use of Internet including search engines and its resources
- E-resources access methods.

Course Code: PGSS 0502

Credit Hours: 0+1

Course Title: Technical Writing and Communications Skills

Objective: To equip the students/scholars with skills to write dissertations, research papers, etc. To equip the students/scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical Technical Writing

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion)
- Writing of abstracts, summaries, précis, citations etc.
- Commonly used abbreviations in the theses and research communications
- Illustrations, photographs and drawings with suitable captions

- Pagination, numbering of tables and illustrations
- Writing of numbers and dates in scientific write-ups
- Editing and proof-reading; Writing of a review article
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks); Error analysis (Common errors)
- Concord
- Collocation
- Phonetic symbols and transcription
- Accentual pattern: Weak forms in connected speech: Participation in group discussion: Facing an interview
- Presentation of scientific papers.

Suggested Reading

1. Chicago Manual of Style. 14th Ed. 1996. Prentice Hall of India.
2. Collins' Cobuild English Dictionary. 1995.
3. Harper Collins. Gordon HM & Walter JA. 1970. Technical Writing. 3rd Ed.
4. Holt, Rinehart & Winston. Hornby AS. 2000. Comp. Oxford Advanced Learner's Dictionary of Current English. 6th Ed. Oxford University Press.
5. James HS. 1994. Handbook for Technical Writing. NTC Business Books.
6. Joseph G. 2000. MLA Handbook for Writers of Research Papers. 5th Ed. Affiliated East-West Press.
7. Mohan K. 2005. Speaking English Effectively. MacMillan India.
8. Richard WS. 1969. Technical Writing.
9. Barnes & Noble. Robert C. (Ed.). 2005. Spoken English: Flourish Your Language.
10. Abhishek. Sethi J & Dhamija PV. 2004. Course in Phonetics and Spoken English. 2nd Ed. Prentice Hall of India.
11. Wren PC & Martin H. 2006. High School English Grammar and Composition. S. Chand & Co.

Course Code: PGSS 0503

Credit Hours: 1+0

Course Title: Intellectual Property and its Management in Agriculture

Objective: The main objective of this course is to equip students and stakeholders with knowledge of intellectual property rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials,

ownership and period of protection; National Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Reading

1. Erbisch FH & Maredia K. 1998. Intellectual Property Rights in Agricultural Biotechnology. CABI.
 2. Ganguli P. 2001. Intellectual Property Rights: Unleashing Knowledge Economy. McGraw-Hill.
 3. Intellectual Property Rights: Key to New Wealth Generation. 2001. NRDC & Aesthetic Technologies.
 4. Ministry of Agriculture, Government of India. 2004. State of Indian Farmer. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
 5. Rothschild M & Scott N. (Ed.). 2003. Intellectual Property Rights in Animal Breeding and Genetics. CABI.
 6. Saha R. (Ed.). 2006. Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies. Daya Publ. House.
- The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; National Biological Diversity Act, 2003.

Course Code: PGSS 0504

Credit Hours: 0+1

Course Title: Basic Concepts in Laboratory Techniques

Objective: To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab
- Handling of chemical substances
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets; washing, drying and sterilization of glassware
- Drying of solvents/chemicals
- Weighing and preparation of solutions of different strengths and their dilution
- Handling techniques of solutions; Preparation of different agro-chemical doses in field and pot applications
- Preparation of solutions of acids
- Neutralisation of acid and bases
- Preparation of buffers of different strengths and pH values
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath
- Electric wiring and earthing. Preparation of media and methods of sterilization

- Seed viability testing, testing of pollen viability
- Tissue culture of crop plants; Description of flowering plants in botanical terms in relation to taxonomy

Suggested Reading

Furr AK. 2000. CRC Hand Book of Laboratory Safety. CRC Press.

Gabb MH & Latchem WE. 1968. A Handbook of Laboratory Solutions. Chemical Publ. Co.

Course Code: PGSS 0505

Credit Hours: 1+0

Course Title: Agricultural Research, Research Ethics and Rural Development Programmes

Objective: To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I

History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II

Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III

Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

Suggested Reading

1. Bhalla GS & Singh G. 2001. Indian Agriculture - Four Decades of Development. Sage Publ.
2. Punia MS. Manual on International Research and Research Ethics. CCS, Haryana Agricultural University, Hisar.
3. Rao BSV. 2007. Rural Development Strategies and Role of Institutions - Issues,

Innovations and Initiatives. Mittal Publ.

4. Singh K.. 1998. Rural Development - Principles, Policies and Management. Sage Publ.