Major Subject: Forage Production (Agronomy)

Semester-I

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Course No.</th>
<th>Title of course</th>
<th>Credit hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>FP-611</td>
<td>Modern concepts in Crop Production</td>
<td>3+0</td>
</tr>
<tr>
<td>2.</td>
<td>FP-612</td>
<td>Soil Fertility and Nutrient Management</td>
<td>2+1</td>
</tr>
<tr>
<td>3.</td>
<td>FP-613</td>
<td>Principles and Practices of Water Management</td>
<td>2+1</td>
</tr>
<tr>
<td>4.</td>
<td>FP-614</td>
<td>Agronomy of Forage Crops</td>
<td>2+1</td>
</tr>
<tr>
<td>5.</td>
<td>SS-611</td>
<td>Concepts of Soil Science</td>
<td>2+1</td>
</tr>
</tbody>
</table>

Semester-II

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Course No.</th>
<th>Title of course</th>
<th>Credit hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>FP-621</td>
<td>Principles and Practices of Weed Management</td>
<td>2+1</td>
</tr>
<tr>
<td>6.</td>
<td>FP-622</td>
<td>Seed Production Agronomy</td>
<td>2+1</td>
</tr>
<tr>
<td>7.</td>
<td>FP-623</td>
<td>Grassland and Pasture Management</td>
<td>2+1</td>
</tr>
<tr>
<td>8.</td>
<td>FP-624</td>
<td>Crop Ecology and Crop Physiology</td>
<td>3+0</td>
</tr>
</tbody>
</table>

Minor Subject: Animal Nutrition

Semester-I

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Course No.</th>
<th>Title of course</th>
<th>Credit hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>AN-614</td>
<td>Non Conventional Feed stuffs and toxic Constituents/Antimetabolites in animal feed Stuffs.</td>
<td>2+2</td>
</tr>
</tbody>
</table>

Semester-II

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Course No.</th>
<th>Title of course</th>
<th>Credit hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>AN-621</td>
<td>Animal Nutrition-Minerals, Vitamins and Feed Additives.</td>
<td>3+1</td>
</tr>
</tbody>
</table>

Supporting subject: Dairy Economics & Statistics.

Semester-I

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Course No.</th>
<th>Title of course</th>
<th>Credit hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>ES-624</td>
<td>Agricultural Finance and Project Management</td>
<td>2+1</td>
</tr>
</tbody>
</table>

Semester-II

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Course No.</th>
<th>Title of course</th>
<th>Credit hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>ES-628</td>
<td>Design of Experiments</td>
<td>3+2</td>
</tr>
<tr>
<td></td>
<td>FP-619</td>
<td>Seminar</td>
<td></td>
</tr>
</tbody>
</table>
Theory

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

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

Effect of lodging 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.

Scientific principles of crop production; crop response production functions; concept of soil-plant relations; yield and environmental stress.

Integrated farming systems, organic farming, and resource conservation technology including modern concept of tillage; dry farming. Determining the nutrient needs for yield potentiality of crop plants, concept of balanced nutrition and integrated nutrient management; precision agriculture.
FP 612: Soil Fertility and Nutrient Management

Theory

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

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

Preparation and use of farm yard manure, compost, green manure, vermi-compost, bio fertilizers and other organic concentrates, their composition, availability and crop responses; recycling of organic wastes and residue management.

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

Time and methods of application of manures and fertilizers; foliar application and its concept; relative performance of manures and fertilizers; economics of fertilizer use; integrated nutrient management; use of vermi-compost and crop residue.

Practical

- Determination of total N, P, K and S in plants.
- Interpretation of interaction effects and computation of economic and yield optima.
- Identification of fertilizers and manures.
Theory

Water and its role in plants; water resources of India, major irrigation projects, extent of area and crops irrigated in India and different states.

Water movement in soil and plant, transpiration; soil-water-plant relationships; water absorption by plants; plant response to water stress, crop plant adaptation to moisture stress conditions. Dry land farming and water management. Water harvesting and moisture conservation techniques.

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

Water management of the crops and cropping systems; quality of irrigation water and management of saline water for irrigation; water use efficiency. 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.

Practical

- Measurement of soil water potential by using tensiometer, and pressure plate and membrane apparatus.
- Soil –moisture characteristics curves.
- Water flow measurements using different devices.
- Determination of irrigation requirements.
- Calculation of irrigation efficiency.
- Determination of infiltration rate.
FP-614: Agronomy of Forage Crops

Theory

Adaptation, distribution, varietal improvement, agro-techniques and quality aspects including anti-quality factors of important fodder crops like maize, Sorghum +Teosinte, bajra, guar, cowpea, oats, barley, berseem, senji, lucerne, mustard, turnip, hybrid napier grass, Guinea grass, rye grass, red clover, white clover, Lasiuras, Cenchrus etc.

Suitable fodder rotations of fodder crops and their mixtures for different agroclimatic zones of the country.

Year–round fodder production. 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 enrichment and biological methods for improving nutritive value of poor quality fodder. Economics of fodder cultivation.

Practical

- Identification of important fodder crops, grasses and weeds.
- Practical training of farm operations in raising of fodder crops.
- Canopy measurement and yield estimation.
- Estimation of pH and amionical nitrogen of silage.
- Maintenance of herbarium.
- Estimation of crude protein, NDF, ADF, lignin, silica, cellulose.
SS 611: Concepts of Soil Science

Theory:
Unit-I: Soil as a natural body and medium for plant growth; nature and origin of soil, soil formation, classification and survey. Soil physical, chemical and biological properties in relation to crop production and soil-water-plant relations.
Unit-II: Types, factors and causes of land degradation, Land capability classification, Problem Soils and their distribution in India. Nature and characteristics of acidic, salt-affected and waterlogged soils of India. Reclamation and management of problem soils, use of amendments and drainage.
Unit-III: Sources of soluble salts and other impurities in water; quality of different water resources in India; factors affecting use of poor quality irrigation water for crop production; management practices for using saline-sodic waters; sewage and industrial effluents for irrigation.
Unit-IV: Crop production techniques in problem soils- crops, varieties, cropping systems and agronomic practices, salt tolerant crops
Unit-V: Fertilizers, insecticides and their effects on soil.

Practical:
- Soil sampling for different purposes
- Soil profile & its characteristics
- Bulk density, particle density and aggregate size analysis of soil
- Identification of fertilizers & their application
- pH, EC and OC determination of soils
- Cation and anions analysis of irrigation water
- Determination of micronutrients Lime and Gypsum requirement of problem soils
FP 621: Principles and Practices of Weed Management 2+1

Theory

Weed biology and ecology, crop-weed competition including allelopathy; principles and methods of weed control and classification.

Herbicides introduction and history of their development; classification based on chemical, physiological application and selectivity; mode and mechanism of action of herbicides. Herbicide structure-activity relationship, factors affecting the efficiency of herbicides; herbicide formulations, herbicide mixtures, weed control through bio herbicides myco-herbicides and allelochemicals; Degradation of herbicides in soil and plants; herbicide resistance in weeds and crops and its management, herbicide rotation.

Weed management in major crops and cropping systems; parasitic weeds, weed shifts in cropping systems; aquatic and perennial weed control. Integrated weed management, cost benefit analysis of weed management.

Practical

- Identification of important weeds and weed seeds.
- Preparation of a weed herbarium.
- Weed survey in crops and cropping systems.
- Crop-weed competition studies.
- Preparation of spray solutions of herbicides for high and low-volume sprayers.
- Use of various types of spray pumps and nozzles and calculation of swath width.
- Economics of weed control.
- Herbicide residue analysis in plant and soil.
- Calculation of herbicidal requirement and diagnosis of herbicide injury.
General principles of seed production and certification. Problems of seed production in India with special reference to forage crops. Seed production techniques and agronomical practices of important cereals, pulses, and forage crops. Seed industry in the country and role of various agencies, seed morphology, seed multiplication chain, seed purity, seed health, dormancy, seed vigor, hybrid seed production, seed treatment, seed viability, seed quality, physiology of seed germination, seed testing for germination and seedling evaluation, seed certification, processing, grading and storage, distribution and marketing, storage grain pests.

**Practical**

Seed sampling and evaluation of seed quality on the basis of purity and germination rouging, detaseling, inspection.
Familiarization with seed processing equipments and materials
Precautions for seed storage
Comparison of farmer’s saved seed with certified seed.
Sowing and maintenance of seed production fields of important crops.
Visits to commercial seed production fields, seed processing plants and sale counters of seed agencies.
Theory
Importance of agrostalogy, principles of grassland ecology; grassland ecology-community, climax, dominant species, succession, biotype, ecological status of grasslands in India, grass cover of India, economic aspects of grasslands, their problems and management. Improvement of grasslands.

Importance, classification, scope, status and research needs of pastures; pasture establishment, management, improvement, renovation and utilization of natural pastures; cultivated pastures.

Development and management of range lands and grasslands, systems of grazing. Suitable grass legume mixtures. Cultivation of important grasses and legumes under irrigated, rainfed and hilly areas. Role of grasses in improvement of soil fertility; Silvi – pasture system and its scope in India. Grazing management. Nutrient management. Importance of agroforestry; agroforestry systems- agrisilviculture, silvipasture, agrisilvipasture, agrihorticulture; alley cropping.

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 silvi-pasture system.
- Seed treatment for better germination.
- Methods of propagation/planting of grasses and trees in silvipastoral system.
- Fertilizer application in strip and silvipastoral systems.
- Estimation of protein content in loppings of important fodder trees.
- Visit to Indian Grassland and Fodder Research Institute, Jhansi and Palampur.

Basic concept and principles of crop ecology, agricultural systems, ecology of cropping systems, principles of plant distribution and adaptation, crop and world food supply; physiological limits of crop yield and variability in relation to the ecological optimum; Ecosystem characteristics, types and functions, terrestrial ecology, flow of energy in ecosystem, ecosystem productivity, biomass, succession and climax concept. Physiological response of crop plants to light, temperature, CO2, moisture and solar radiation; influence of climate on photosynthesis and productivity of crops; effect of global climate change on crop production.

Exploitation of solar energy in crops; vertical distribution of temperature; efficiency in crop production. Competition in crop plants; environmental pollution, ecological basis of environmental management and environment manipulation through agronomic practices.
FORAGE RESEARCH AND MANAGEMENT CENTRE
NATIONAL DAIRY RESEARCH INSTITUTE, KARNAL
Ph. D. AGRONOMY (FORAGE PRODUCTION)

Major Field: Agronomy (19 Credits)
Minor Field: Animal nutrition (09 Credits)
Supporting Field: (03Credits)
Seminar: (02Credits)
Thesis: (45Credits)
Total (Minimum) (75Credits)

Semester-wise Distribution of Courses

<table>
<thead>
<tr>
<th>Course No.</th>
<th>Name of the Courses</th>
<th>L</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Semester</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FP 711</td>
<td>Modern Concepts in Agronomy *</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>FP 712</td>
<td>Advances in weed management</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>FP 713</td>
<td>Recent Trends in fodder and pasture crops production*</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>FP 714</td>
<td>Soil fertility and Nutrient management</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>FP 715</td>
<td>Experimental techniques in Agronomy*</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Minor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II Semester</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FP 721</td>
<td>Principles and Practices of Organic Farming</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>FP 722</td>
<td>Recent Concept of water management</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>FP 723</td>
<td>Advances in Seed production and management</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>FP 724</td>
<td>Agrostology and Agroforestry</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>FP 725</td>
<td>Crop Ecology and Climate Change</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>FP 726</td>
<td>Farming Systems</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Minor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supporting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III-VI Semester</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FP 731</td>
<td>Seminar</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>FP 732</td>
<td>Research</td>
<td>0</td>
<td>45</td>
</tr>
</tbody>
</table>

*Core courses for Ph.D.
COURSE STRUCTURES FOR Ph.D. AGRONOMY (FP)
FP 711: MODERN CONCEPTS IN AGRONOMY  3(3+0)

SEM-I
Objective:
To acquaint the students about the recent developments in agronomy and resource management.

Theory:
UNIT I
Environmental concerns related to intensive use of agricultural inputs. Sustainable agriculture - need, scope, practices and economic evaluation, holistic approach of farming systems. Agro-physiological basis of variation in yield, role of agro-biodiversity in sustainable food production, GM crops, crop diversification for improved food and nutritional security.

UNIT II
Conservation agriculture, modern approaches for improving resource-use efficiency, crop residue management in multiple cropping systems. Principles and practices of conservation tillage and watershed management, carbon sequestration.

UNIT III
Precision farming - current status and opportunities for adoption in India. GIS, GPS and remote sensing for crop management, global warming.

UNIT IV
Contract farming - concept, scope, partnerships, types, characteristics, management and administration, problems and advantages for farmers/ sponsors, WTO issues in agriculture.

UNIT V
Crop modeling, systems classification; flow charts, modeling techniques and methods of integration - state, rates and driving variables, feedbacks and relational diagrams information technology, elementary models for crop growth based on basic methods of classical growth analysis.

UNIT VI
Protected agriculture - concept, characteristics, types, scope and limitations in India. Plant nutrition - challenges and tasks ahead. Stress crop production.

Suggested Readings:

Objective: To teach about the changing weed flora, new herbicides, their resistance, toxicity, antidotes and residue management under different cropping systems.

Theory
UNIT-I: Crop-weed competition in different cropping situations; changes in weed flora, various causes and effects.
UNIT-II: Physiological and biological aspects of herbicides, their absorption, translocation, metabolism and mode of action; selectivity of herbicides and factors affecting them.
UNIT-III: Climatic factors and phytotoxicity of herbicides; fate of herbicides in soil and factors affecting them, residue management of herbicides, adjuvants.
UNIT-IV: Advances in herbicide application techniques; herbicide resistance; antidotes and crop protection compatibility of herbicides of different groups; compatibility of herbicides with other pesticides.
UNIT-V: Development of transgenic herbicide resistant crops; herbicide development, registration procedures.
UNIT-VI: Relationship of herbicides with tillage, fertilizer and irrigation; bioherbicides, allelochemical herbicide bioassays.

Suggested Readings
Objective:
To teach the crop husbandry, conservation and utilization of different fodder crops, pastures and tree-forage crop-based systems

Theory:
UNIT I: Introduction, origin, history, distribution, adaptation, classification, climate, soil, varieties, water, weed management and nutrient requirement of important cultivated fodder crops like maize, pearl millet, teosinte, cluster bean, cowpea, oats, barley, berseem, senji, lucerne etc.

UNIT II: Introduction, origin, history, distribution, adaptation, classification, climate, soil, varieties, water, weed management and nutrient requirement of important forage crops/grasses/legumes, like, napier and hybrid napier grass, guinea grass, *Lasiurus*, buffel grass, stylo, suitable weed flora for fodder etc.

UNIT III: Anti-quality factors of important fodder crops, forage grasses and legumes. 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.

UNIT IV: Natural grasslands of India. Establishment of pastures and their management with special reference to weed control and fertilization including micronutrients important to animals, defoliation and its effects, regeneration of infested pastures.

UNIT V: Wasteland development - selection of species, planting methods and problems of seed germination in agro-forestry systems. Lopping and coppicing in agro-forestry systems.

Practicals:
- Practical training of farm operations in raising fodder crops, canopy measurement.
- Yield and quality estimation, viz. crude protein, NDF, ADF, lignin, silica, cellulose etc. of various fodder and forage crops.
- Anti-quality components like HCN in sorghum and such factors in other crops.
- Hay and silage making
- Identification of seeds and plants of common grasses, legumes and trees of economic importance with reference to agro-forestry.
- Methods of propagation/planting of grasses, trees in silvipastoral system.
- Fertilizer application in strip and silvi-pastoral systems.
- Visit to IGFRI / NRCAF, Jhansi.

Suggested Readings:
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.

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.
UNIT-IV: Commercial fertilizers; composition, relative fertilizer value and cost; crop response to different nutrients, residual effects and fertilizer use efficiency, fertilizer mixtures and grades; agronomic, chemical and physiological 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 manures; economics of fertilizer use; integrated nutrient management; use of vermin compost and residue wastes in crops.

Practicals
- Determination of total N, P, K and S in plants
- Interpretation of interaction effects and computation of economic and yield optima

Suggested Readings
SEM-I

Objective: To teaching methodology of planning, layout, data recording, analysis, interpretation and report writing of agronomic experiments

Theory:
UNIT I-Historical aspects of field experimentation, principles and practices of field experimentation
UNIT II-Identification of research problem and preparation of research project proposal. Presentation of data and report writing.
UNIT III-Planning of experiments, recording of data - before layout of experiment, during crop growth and after harvest. Selection of experimental design, layout of experiment, number of treatments / replications, plot size, border effect etc. Techniques for increasing the precision for an experiment.
UNIT III-Interpretation of data from weed control, irrigation, fertilizer and cropping system experiments. Interactions in factorial experiments.
UNIT IV-Contrast analysis, pooled analysis, data transformation. Evaluation of direct, residual and cumulative effects of treatments
UNIT V-Correlation and regression analysis, and their application. Energetics and economic analysis.
UNIT VI-Analysis of data of typical agronomic experiments. Nutrient and water balance sheets. Statistical softwares and their application.

Practicals:
- Practical considerations in field experimentation.
- Overview of softwares in agricultural research and analysis of data.
- Analysis of data of field experiments and Use of excel in data analysis.
- Statistical analysis of data using MSTATC.
- Calculation and interpretations of interactions of factorial experiments.
- Calculation of direct, residual and cumulative effects of treatments in cropping systems.
- Exercise on confounding designs.
- Exercise on data transformation.
- Exercise on missing plot analysis.
- Exercise on pooled analysis of data over years/locations.
- Exercise on linear regression equation.
- Exercise on quadratic regression equation.
- Economic analysis of field crop production.
- Exercise on determination of optimum economic dose of fertilizers.

Suggested Readings:

FP 721: PRINCIPLES AND PRACTICES OF ORGANIC FARMING 3(2+1)
SEM-II
Objective: To teach the principles and practices of organic farming for sustainable crop production.
Theory:
UNIT I: Definition, concepts, history and importance of organic farming; organic production scenario in the world, relevance and scope in India, principles, myths and constraints. Limitations of organic farming.
UNIT III: Package of practices for organic crop production – farm designing, crop planning, site selection, conversion period, conservation tillage, selection of seed / seedlings, availability and use of organic inputs, viz. vermicompost, biofertilizers, compost, green manures for crop nutrition, water and weed management, crop protection, harvesting and post harvesting processing / care.
UNIT IV: Production technology and availability of different organic inputs, viz. vermicompost, biofertilizers, improved compost, green manure, bio-pesticides and plant products, crop-specific package of practices for organic production of different food, vegetable and flower crops.
UNIT V: Changes in physical, microbiological and chemical properties of soil. Evaluation of soil and produce quality. Certification of organic produce and process, certification agencies, group certification, marketing, success stories, potential organic production areas/ crops of India.
Practicals:
- Technique of bio fertilizers application and their response in crops.
- Technique of bio-pesticide and pheromones application and their response in crops.
- Quality standards, inspection, certification and labeling and accreditation procedures for farm produce from organic farms.
- Techniques of growing green manure crops.
- Visit to National Centre for Organic Farming (NCOF).
- Visit to blue-green algae centre of IARI, vermin-compost and bio-fertilizers production unit.
- Visit to bio-pesticide production units, Centre for Protected Crop Production, organic crop production farm.
Suggested Readings:
FP 722: RECENT CONCEPTS OF WATER MANAGEMENT 3(2+1)

SEM-II

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

Theory:
UNIT I: Water and its role in plants; water resources of India, major irrigation projects, extent of area and crops irrigated in India and different states. Soil-plant-atmosphere continuum, soil 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.
UNIT II: Soil, plant and meteorological factors determining water needs of crops; scheduling, depth and methods of irrigation; micro-irrigation system; fertigation; management of water in controlled environments and polyhouses
UNIT III: Water management of crops and cropping systems, management of soil moisture stress and plant growth, strategies of using limited water supply, quality of irrigation water and management of saline water for irrigation, water-use efficiency.
UNIT IV: Water stress – deficit and excess, its effect on growth and development, water stress injury and resistance, management of water stress through soil and crop manipulations, excess of soil water and plant growth; water management in problem soils
UNIT V: Drainage - concept and classification. Field drainage systems with special emphasis on crop production and soil salinity. Inter-relationship of drainage with cropping patterns and types of farming. Drainage requirement of crops and methods of field drainage, their layout and spacing
UNIT VI: Land suitability for irrigation, land irrigability classification; integrated water management in command areas, institution of water management in commands, farmer’s participation in command areas; irrigation legislation.

Practicals:
- Measurement of soil water potential by using tensiometer, and pressure plate and membrane apparatus.
- Preparation of soil-moisture characteristics curves.
- Water flow measurements using different devices.
- Determination of irrigation requirement and irrigation efficiency.
- Determination of infiltration rate, saturated/unsaturated hydraulic conductivity.
- Estimation of drain spacing under surface and sub-surface method.
- Soil moisture constants and measurement.
- Measurement of evapo-transpiration and water requirement of crops.
- Water management experiments – planning, conduct, recoding of data and interpretation

Suggested Readings:
Objective: To teach the basic principles of seed production

Theory
UNIT-I General principles of seed production.
UNIT-II Problems of seed production in India with special reference to forage crops, grasses and fodder trees.
UNIT-III Seed production techniques and agronomical practices of important forage crops, grasses and fodder trees including GM crops.
UNIT-IV Seed industry in the country and role of various agencies, seed morphology, seed multiplication chain, seed purity, seed health, dormancy, seed vigor, hybrid seed production, seed treatment, seed viability, seed quality, physiology of seed germination, seed testing for germination and seedling evaluation,
UNIT-V Seed certification, processing, grading and storage, distribution and marketing and management of storage grain, control of storage grain pests.

Practicals
- Seed sampling and evaluation of seed quality on the basis of purity and germination rouging, detaseling, inspection.
- Familiarization with seed processing equipments and materials
- Precautions for seed storage
- Comparison of farmer’s saved seed with certified seed.
- Sowing and maintenance of seed production fields of important crops.
- Visits to commercial seed production fields, seed processing plants and sale counters of seed agencies.
Objective: To teach crop husbandry of different forage, fodder and agroforestry crops/trees along with their processing.

Theory
UNIT-I: Agrostology: definition and importance; principles of grassland ecology: grassland ecology – community, climax, dominant species, succession, biotype, ecological status of grasslands in India, grass cover of India; problems and management of grasslands.
UNIT-II: Importance, classification (various criteria), scope, status and research needs of pastures; pasture establishment, their improvement and renovation-natural pastures, cultivated pastures; common pasture grasses.
UNIT-III: Agroforestry: definition and importance; agroforestory systems, agrisilviculture, silvipasture, agrisilvipasture, agrihorticulture, aquasilviculture, alley cropping and energy plantation.
UNIT-IV: Crop production technology in agro-forestry and agrostology system; silvipastoral system: meaning and importance for wasteland development; selection of species, planting methods and problems of seed germination in agro-forestry systems; irrigation and manuring in agro-forestry systems, lopping and coppicing in agro-forestry systems, nutritive value of trees; tender operation; desirable tree characteristics.

Practicals
• Preparation of charts and maps of India showing different types of pastures and agroforestry 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
• 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
• Economics of agro-forestry
• Visit to important agro-forestry research stations

Suggested Readings

Tejwani KG. 1994. *Agroforestry in India*. Oxford & IBH.
FP 725: CROP ECOLOGY AND CLIMATE CHANGE 3(3+0)

SEM - II

Objective: To acquaint the students about the agricultural systems, agro-ecological regions, and adaptation of crops to different agro-climatic conditions.

Theory
UNIT-I: Concept of crop ecology, agricultural systems, ecology of cropping systems, principles of plant distribution and adaptation, crop and world food supply.
UNIT-II: Ecosystem characteristics, types and functions, terrestrial ecology, flow of energy in ecosystem, ecosystem productivity, biomass, succession and climax concept.
UNIT-III: Physiological response of crop plants to light, temperature, CO2, moisture and solar radiation; influence of climate on photosynthesis and productivity of crops.
UNIT-IV: Exploitation of solar energy in crops; vertical distribution of temperature; efficiency in crop production.
UNIT-V: Competition in crop plants; environmental pollution, ecological basis of environmental management and environment manipulation through agronomic practices; improvement of unproductive lands through crop selection and management.
UNIT-VI: Effect of global climate change on crop production and climate resilient forage production.

Suggested Readings
Objective:
To appraise about cropping and farming systems, types of integrated farming systems under different agro-ecosystems, farming systems research and optimization methodologies.

Theory:
UNIT I - Cropping systems – definition, indices, production potential, resource management in cropping systems, production potential under monoculture, multiple cropping, alley cropping, intercropping, multi-storeyed cropping. Yield advantages in intercropping systems.
UNIT II - Farming systems - definition and importance; classification of farming systems, characteristics, objectives and principles. Concept of sustainability in farming systems; efficient farming systems; natural resources - identification and management.
UNIT III - Production potential of different components of farming systems. Cropping systems: as an important component of FS, remunerative cropping systems, crop diversification.
UNIT IV - Integrated farming systems for different agro-ecosystems, interactions and resource recycling among different enterprises.
UNIT V - Farming system research methodologies: on-farm research, on-station research and system modeling. Preparation of different farming system models; evaluation of different farming systems. Case studies on different farming systems. Multi-criteria decision making and optimization methodologies for designing integrated farming systems.

Practicals:
- Indices for assessing cropping system efficiency.
- Measurement of competition effects in intercropping systems.
- Farming system analysis: Participatory Rural Appraisal, Rapid Rural Appraisal, diagnostic survey.
- Farming system analysis: Interaction with farmers, problem identification, and prioritization and development projects/interventions for solutions to the identified problems.
- Use of optimization software for developing models, formation of matrix and drawing of different scenarios,
- Handling single objective LP model, Handling multi-objective LP model and analysis of data for risk analysis, resource allocation and enterprise selection decisions.
- Visit to apiary, vermin-compost, mushroom production and biogas production unit, integrated farming systems

Suggested Readings: