ಕೆಳದಿ ಶಿವಪ್ಪ ನಾಯಕ
ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕೆ ವಿಜ್ಞಾನಗಳ ವಿಶ್ವವಿದ್ಯಾಲಯ
ಶಿವಮೊಗ್ಗ

Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences

Shivamogga

MINOR COURSES

(A) M.Sc. (Agri.)

(B) M.Sc. (Horti.)

(C) M.Sc. (Forestry)

DIRECTORATE OF POST GRADUATE STUDIES

ನೇಗಿಲ ಮೇಲೆಯೇ ನಿಂತಿದೆ ಧರ್ಮ

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University of Agricultural and Horticultural Sciences
Shivamogga

MINOR , SUPPORTING AND COMMON COURSE SYLLABI FOR MASTER'S DEGREE PROGRAMMES

Revised syllabus as per BSMA
2022-2023

DIRECTORATE OF POST GRADUATE STUDIES

KELADI SHIVAPPA NAYAKA
UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES,
SHIVAMOGGA

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CONTENTS

MINOR COURSES

AGRICULTURAL ECONOMICS

Course Title with Credit Load

M.Sc. (Agri.) in Agricultural Economics

Course Code	Course Title	Credit Hours
AEC-501	Micro Economic Theory And Applications	3 (3+0)
AEC-502	Agricultural Production Economics	2 (1+1)
AEC-503	Agricultural Marketing and Price Analysis	3 (2+1)
AEC-504	Macro Economics And Policy	2 (2+0)
AEC-505	Econometrics	3 (2+1)
AEC- 506	Agricultural Development and Policy Analysis	2 (2+0)
AEC-507	Agricultural Finance and Project Management	3 (2+1)
AEC-508	Linear Programming	2 (1+1)
AEC-509	Research Methodology for Social Sciences	2 (1+1)
AEC-510	Indian Economy: History and Contemporary Issues	2 (2+0)
AEC-511	International Economics	

Course Contents
M.Sc. (Agri.) in Agricultural Economics

I. Course Title : Micro Economic Theory and Applications

II. Course Code : AEC-501

III. Credit Hours : 3(3+0)

IV. Why this course?

Markets form an integral part of the economy. They are governed by demand and supply mechanism with profit making its ultimate goal. Thus, it is imperative to eXpose the students towards how the markets function, their types and how the buyers and sellers behave. That will help them make correct decision when it comes to price setting and choice of product.

V. Aim of the course

The course envisages the concepts and principles embodying micro-economics. The economic problems, functioning of price mechanism, theory of household behaviour and consumer's demand function. Theory of firm, supply determinants, determination of price under different market structures and factor pricing (micro economic components).

VI. Organisation of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to micro-economics	1. Basic Concepts : A review
2.	Insight of consumer, production and cost involved	1. Consumer Choice 2. Production and Cost
3.	Overview of market	1. Market Forms 2. Factor Markets

VII. Theory

Block 1: Introduction to micro-economics

Unit 1: Basic Concepts: A review

Scarcity and Choice; Production possibility frontier, Positive and normative economics; concepts of opportunity cost, Demand and Supply: determinants of individual demand/supply; demand/ supply schedule and demand/ supply curve; market versus individual demand/ supply; shifts in the demand/ supply curve

Block 2- Insight of consumer, production and cost involved

Unit 1: Consumer Choice

Cardinal Utility Approach – Ordinal Utility Approach -Budget sets and Preferences under different situations – Hicks and Slutsky income and substitution effects –

Applications of Indifference curve approach – Revealed Preference Hypothesis – Consumer surplus – Derivation of Demand curve – Elasticity of demand – Demand and supply together; how prices allocate resources; controls on prices – price floor and price ceiling – applications in agriculture.

Unit 2: Production and Cost

Production functions: single variable - average and marginal product, variable proportions, stages of production. Two variables - isoquants, returns to scale and to a factor; factor prices; Technical progress; cost minimization and output maximization; Elasticity of substitution. Expansion path and the cost function Concept of economic cost; Short run and long run cost curves; increasing and decreasing cost industries; envelope curve; L-shaped cost curves; economies of scale; revenue and expenditure, elasticity and marginal revenue; Firm equilibrium and profit.

Block 3: Overview of market

Unit 1: Market Forms

Behaviour of profit maximizing firms and the production process- Perfect competition: Equilibrium of the market. Long run industry supply, applications: effects of taxes and subsidies; Monopoly: Equilibrium; supply; multiplant firm; monopoly power; deadweight loss; price discrimination; Monopolistic Competition: Product differentiation; equilibrium of the firm in the industry-with entry of new firms and with price competition. Comparison with pure competition. Duoploy: Cournot model and reaction curves; Stackelberg's model, Bertrand model; Oligopoly.

Unit 2: Factor Markets

Labour and land markets - basic concepts (derived demand, productivity of an input, marginal productivity of labour, marginal revenue product); demand for labour; input demand curves; shifts in input demand curves; competitive labour markets; Economic rent and quasi rent.

VIII. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions on practises done by firms.
- Power point presentations by students.
- Exploring the agricultural market and identification of industries and their type.

IX. Learning outcome

After completion of the course the student will be able to :

- Get acquainted with the basic concepts of market functions.
- Build up vision towards how consumers makes choices and market reaches the equilibrium.
- Develop decision making skill for firms about product selections and scale of production to ensure maximum profit.
- Understand about different types of markets existing in the real world, their principles and whereabouts.

X. Suggested Reading

- Koutsoyiannis A. Modern Micro Economics. Macmillan Press Ltd
- Ferguson and Gould. Micro Economic Theory. Richard D Erwin Inc., USA
- Richard A. Bilas, Micro Economic Theory.
- Leftwich Richard H. The Price System and Resources Allocation
- Allen CL. A Frame Work of Price Theory.

I. Course Title : Agricultural Production Economics

II. Course Code : AEC-502

III. Credit Hours : 2 (1+1)

IV. Why this course?

Production in agriculture is the outcome of the input factors involved. In this competitive and uncertain market, it is important that the farmers take the right decision about the combination of inputs that will result in higher income. Thus, as an economist it is a pre-requisite that the students understand the interaction between output and input. And work out the most effective production plan.

V. Aim of the course

To expose the students to develop the concept, significance and uses of production economics. To understand the relationships between factors and output. To learn how to decide the combination of inputs to be used as per the resources available. Ensure that the production process works efficiently.

VI. Organization of the course

The course is organised as follows-

No	Block		Unit
1.	Introduction to production economics	1.	Concepts of production economics
2.	Factors and costs	1.	Factors and theory of production
		2.	Concepts of costs
3.	Assessment	1.	Dynamics of assessment

VII. Theory

Block 1: Introduction to Production Economics

Unit 1: Concepts of production economics

Nature, scope and significance of agricultural production economics- Agricultural Production processes, character and dimensions-spatial, temporal - Centrality of production functions, assumptions of production functions, commonly used forms - Properties, limitations, specification, estimation and interpretation of commonly used production functions.

Block 2: Factors and costs

Unit 1: Factors and theory of production

Factors of production, classification, interdependence, and factor substitution -Determination of optimal levels of production and factor application -Optimal factor combination and least cost combination of production - Theory of product choice; selection of optimal product combination.

Unit 2: Concepts of cost

Cost functions and cost curves, components, and cost minimization -Duality theory cost and production functions and its applications -Derivation of firm's input demand and output supply functions -Economies and diseconomies of scale.

Block 3: Assessment

Unit 1: Dynamics of economic assessment

Technology in agricultural production, nature and effects and measurement - Measuring efficiency in agricultural production; technical, allocative and economic efficiencies - Yield gap analysis-concepts-types and measurement - Nature and sources of risk, modeling and coping strategies.

VIII. Practical

- Different forms of production functions
- Specification, estimation and interpretation of production functions
- Returns to scale, factor shares, elasticity of production
- Physical optima-economic optima
- Least cost combination
- Optimal product choice
- Cost function estimation, interpretation
- Estimation of yield gap
- Incorporation of technology in production functions
- Measuring returns to scale-risk analysis.

IX. Teaching Methods/ Activities

- Lectures
- Assignments (Group/individual)
- Group Discussions on working out
- Power point presentations by students
- Exploring the agricultural market and identification of industries and their type.

X. Learning outcome

After the successful completion of the course the student will be able to— Understand how the factors and output interact with each other. - Work out whether the production system is working efficiently and point out the loop holes.- Apply the knowledge of costs and profits to work out the demand and supply functions. This will result into more efficient decision making.

XI. Suggested Reading

- EO Heady. Economics of Agricultural Production and resources use.
- John P Doll and Frank Orazem. Production Economics: Theory with application
- Heady EO & Dillon JL. 1961. Agricultural Production functions. Kalyani Publishers, Ludhiana, India. 667 p.
- Baumol WG. 1973. Economic theory and operations analysis. Practice Hall of India Private Limited, New Dehli.626 p.
- Gardner BL & Rausser GC. 2001. Handbook of Agricultural Economics Vol. I Agricultural Production. Elsevier.

I. Course Title : Agricultural Marketing and Price Analysis

II. Course Code : AEC 503

III. Credit Hours : 3 (2+1)

IV. Why this course?

The ultimate aim of production process is to sell the produce in the market and generate income. Markets serves as platform where this exchange takes place. Agriculture markets are different from other markets due to the nature of the commodity. Thus, it is important to develop a strong foundation of agricultural marketing, its components and issues. The student needs to know about the multi- pronged ways of marketing the produce, agencies involved. In this modern era, it is important to understand how technology is transforming this sector.

V. Aim of the course

The course is designed to acquaint the students about the basics of dynamics of agricultural marketing. The content includes supply, demand and marketing of farm production, marketing functions and channels, marketing costs, margins and efficiency, agricultural prices, New marketing formats like e-marketing, e-NAM future trading, supply chain management, market intelligence etc.

VI. Organization of the course

The course is organised as follows:

No	Block		Unit
1.	Introduction to agricultural marketing	1.	Introduction to agricultural marketing
2.	Agricultural markets	1.	Aspects of agricultural marketing
		2.	Future marketing and government
3.	Advances in agricultural marketing	1.	Use of information technology
		2.	Dynamics of price

VII. Theory

Block 1: Introduction to Agricultural Marketing

Unit 1: Introduction to agricultural marketing

New Concepts in Agricultural Marketing - Characteristic of Agricultural product and Production – Problems in Agricultural Marketing from Demand and Supply and Institutions sides. Market intermediaries and their role - Need for regulation in the present context - Marketable & Marketed surplus estimation. Marketing Efficiency - Structure Conduct and Performance analysis - Vertical and Horizontal integration - Integration over space, time and form-Vertical co-ordination.

Block 2: Agricultural Markets

Unit 1: Aspects of agricultural marketing

Different Forms of marketing: Co-operatives Marketing – APMC Regulated Marketing - Direct marketing, Farmer Producer Companies, e-NAM and marketing under e-NAM, e-marketing Contract farming and Retailing, Organized retailing - Supply Chain Management - State trading, Warehousing and other Government agencies -Performance and Strategies -Market infrastructure needs, performance and Government role - Value Chain Finance.

Unit 2: Future marketing and government

Introduction to Commodities markets and future trading - Basics of commodity futures - Operation Mechanism of Commodity markets – Price discovery - Hedging and Basis - Fundamental analysis - Technical Analysis – Role of Government/SEBI in promoting commodity trading and regulatory measures.

Block 3: Advances in Agricultural Marketing

Unit 1: Use of Information Technology

Role of Information Technology and Market Intelligence in marketing of agricultural commodities, -electronic auctions (e-bay), e-Chaupals, Agmarknet and Domestic and Export market Intelligence Cell (DEMIC).

Unit 2: Dynamics of price

Price forecasting – time series analysis – time series models – spectral analysis. Price policy and economic development – non-price instruments.

VIII. Practical

- Supply and demand elasticities in relation to problems in agricultural marketing.
- Price spread and marketing efficiency analysis.
- Marketing structure analysis through concentration ratios.
- Performance analysis of Regulated market and marketing societies. Analysis on contract farming and supply chain management of different agricultural commodities, milk and poultry products.
- Supply Chain Analysis - quantitative estimation of supply chain efficiency.
- Market Intelligence – Characters, Accessibility, and Availability Price forecasting.
- Online searches for market information sources and interpretation of market intelligence reports – commodity outlook.
- Technical Analysis for important agricultural commodities.
- Fundamental Analysis for important agricultural commodities.
- Presentation of the survey results and wrap-up discussion.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on price volatility and control measures prevailing.
- Power point presentations by students on government schemes.
- Visit to eNAM mandies, Warehouses, etc.

X. Learning outcome

After the completion of this course the student will be able to–

- Understand the whereabouts of agricultural marketing.
- The different forms of marketing existing in this sector.
- Gain expertise in market intelligence and price forecasting.

XI. Suggested Reading

- Acharya SS & Agarawal NL. 2004. Agricultural Marketing in India. Oxford and IBH Publishing company Pvt. Ltd. New Delhi.
- Acharya SS & Agarawal NL. 1994. Agricultural Prices-Analysis and Policy. Oxford and IBH Publishing company Pvt. Ltd. New Delhi.
- Richard H Kohls and Joseph N. Uhl: Marketing of Agricultural products by Collier MacMillan International.

I. Course Title : Macro Economics and Policy

II. Course Code : AEC-504

III. Credit Hours : 2 (2+0)

IV. Why this course?

The economy of the nation is governed by certain rules, regulation and principles. The students has to gain knowledge of the mechanism through which the large economies are controlled and ensure that welfare prevails. They are entitled to know the transactions between different markets and policies framed to keep value of money under control.

V. Aim of the course

The course envisages the concepts and principles of macroeconomics from classical to Keynesian theories. The other component deals with the monetary system- money, credit and banking system, value of money and economic activities, national income accounting and approaches to estimate national income theory of income and employment determination and inflation.

VI. Organization of the course

The course is organised as follows:

No	Block		Unit
1.	Conceptualising Macro economics	1.	Introduction: Measurement and Concepts
2.	Theories of macroeconomics	1.	Classical Macroeconomics
		2.	Income and spending: Keynesian Framework
3	Money, Consumption and Inflation	1.	Money, Interest and Income
		2.	Theories of Aggregate Consumption and Investment
		3.	Inflation and Unemployment

VII. Theory

Block 1: Conceptualising Macro Economics

Unit 1: Introduction: Measurement and Concepts

Basic concepts and scope of Macro-economics, National Income Accounting: Methods of measurement of key macro-economic aggregates, relationship of national income and other aggregates (with numerical exercises), real and nominal income

Block 2: Theories of macroeconomics

Unit 1: Classical Macroeconomics

Say's Law, Quantity Theory of Money, aggregate labour supply and demand of labour, Classical theory of determining output, wages and prices.

Unit 2. Income And Spending: Keynesian Framework

Simple Keynesian model of income determination; Keynesian Multiplier- aggregate spending, taxation, transfer payments, foreign spending, balanced budget; budget surplus (with numerical exercises).

Block 3- Money, Consumption and Inflation

Unit 1: Money, Interest and Income

Goods market equilibrium-IS curve; Demand for Money, the Liquidity Preference Theory – Liquidity Trap; asset market equilibrium- LM curve; simultaneous equilibrium in goods and asset market-effect of fiscal and monetary policy

Unit 2: Theories of Aggregarte Consumption and Investment

Absolute Income Hypothesis, Relative Income Hypothesis, Fisher's Inter-temporal Choice Model, Life-Cycle and Permanent Income Hypotheses; Profits and Accelerator Theory.

Unit 3: Inflation and Unemployment

Inflation: Nature, Effects and control; Types of inflation – demand pull, cost push- stagflation, core inflation, hyperinflation; Phillips curve.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on inflation.

IX. Learning outcome

After the completion of the course the student will be able to-Understand the concepts of national income, theories build up to understand macroeconomics. Understand better about the policies and government steps taken to control the economic transaction of the nation. Workout how the investment acts as a catalyst in national development.

X. Suggested Reading

- Stonier & Hegue. A Text Book of Economic Theory
- Samuelson PA. 1948. Foundation of Economic Analysis. Harvard University Press
- MC Vaish Allid. 1983. Macro–Economics Theory
- Gardner Ackley. 1961. Macro–Economics Theory: Macmillan, New York.
- TF Dernburg & DM Mcdougali-Macro Economics
- G. Sirkin – Introduction to Macro–Economics Theory
- RL Heibroker-Understanding Macro–Economics

- JK Mehta –Macro Economics
- Michael R Edgemand – Macro-Economics: Theory & Policy
- David' W Pearce –The dictionary of modern Economics

I. Course Title : Econometrics

II. Course Code : AEC 505

III. Credit Hours : 3 (2+1)

IV. Why this course?

Development of analytical skills is imperative to make students proficient in conducting quality research work. The knowledge of variables, their models, and problems encountered when dealing with variables will build up a compatibility with the analytical aspects.

V. Aim of the course

The course provides knowledge of the econometric methods like time series analysis, linear regression models and their application in economic analysis. The course provides an insight into the econometric problems in analyzing time series and cross section data.

VI. Organization of the course

The course is organised as follows:

No	Block		Unit
1.	Introduction to econometrics	1.	Introduction
2.	Classical Regression	1.	Classical Linear Regression
		2.	Breaking down of Classical assumptions
3.	Qualitative Variables	1.	Qualitative variables and simultaneous equation models

VII. Theory

Block 1: Introduction to Econometrics

Unit 1: Introduction

Relationship between economic theory, mathematical economics, models and econometrics, methodology of econometrics-regression analysis.

Block 2: Classical Regression

Unit 1: Classical Linear Regression

Basic two variable regression – assumptions estimation and interpretation approaches to estimation – OLS and their properties – extensions to multi-variable models-multiple regression estimation and interpretation.

Unit 2: Breaking down of Classical assumptions

Violation of assumptions – identification, consequences and remedies for Multicollinearity, heteroscedasticity, autocorrelation – data problems and remedial approaches – model misspecification.

Block 3: Qualitative Variables

Unit 1: Qualitative variables and simultaneous equation models

Use of dummy variables- Introduction to simultaneous equations- identification problem

VIII. Practical

- Single equation two variable model specification and estimation
- Hypothesis testing transformations of functional forms and OLS application
- Estimation of multiple regression model
- Testing and correcting specification errors
- Testing and managing Multicollinearity
- Estimation of regressions with dummy variables

IX. Teaching Methods/ Activities

- Lectures.
- Assignments (Group/individual).

X. Learning outcome

After the completion of the course, the student will be able to-Understand the variables and the properties of regression models. Identify the problems in variables and remove them before conducting the analysis and avoid biased results.

XI. Suggested Reading

- Dorfman R. 1996. Linear Programming and Economic Analysis. McGraw Hill.
- Greene WH. 2002. Econometric Analysis. Pearson Education.
- Johnston J and Dinardo J. 2000. Econometric Methods. Mc Graw-Hill.
- Koutseyianis, A. 1997. Theory of Econometrics. Barner & Noble.
- Maddala GS. 2002. Econometrics. Mc Graw-Hill.
- Pinndyck RS and Rubinfeld DL. 1990. Econometric Models and Econometric Forecasts. McGraw Hill.

I. Course Title : Agricultural Development and Policy Analysis

II. Course Code : AEC-506

III. Credit Hours : 2(2+0)

IV. Why this course?

The ultimate aim of the economies is to attain a satisfactory level of development. Development ensures that there is not only increase in income but also the distribution is such that lesser inequalities eXist. The students need to know what is development and its related concepts. All the policies framed are with one sole objective of increasing the welfare. Thus, once concept of development is build up, students can better understand policies and their genesis.

V. Aim of the course

Concept of economic development and policy, theories of development, performance of Indian agriculture. The process and implementation of policies over a period of time.

VI. Organization of the course

The course is organised as follows:

No	Block		Unit
1.	Basic concepts	1.	Introduction
2.	Theoretical Concepts	1.	Theories of Agricultural Development
3.	Performance and policies	1. 2.	Performance of Indian Agriculture Agricultural Policy: Process and Implementation

VII. Theory

Block 1: Introduction

Unit 1: Introduction

Role of agriculture in economic/ rural development – Evolution of thinking on agriculture and development; Agricultural development – meaning, stages and determinants – Population and food supply – need for sound agricultural policies

Block 2: Theoretical Concepts

Unit 1: Theories of Agricultural Development

Resource exploitation model- Conservation model- Location (Urban impact) model- Diffusion model- High pay-off input model-Induced Innovation Model- Agricultural R&D and Linkages

Block 3: Performance and policies

Unit 1: Performance of Indian Agriculture

Agrarian structure and land relations; trends in performance and productivity; agrarian structure and technology; credit, commerce and technology; capital formation; subsidies; pricing and procurement; Post Green Revolution agriculture; Production and productivity crisis in agriculture; Regional differences; Food Security, PDS system and Malnutrition.

Unit 2: Agricultural Policy: Process and Implementation

Instruments of Agricultural Policy; Process of agricultural policy formulation, implementation, Monitoring and Evaluation in India; Global experiences in participatory approach to Agricultural policy process; critical review of various elements of Indian agricultural policy-resource policies - credit policies - input and product marketing policies - price policies; WTO - Agreement on Agriculture; Planning models. Planning for utilization of resources and Indian Five Year Plans.

VIII. Teaching Methods/ Activities

- Lectures.
- Assignments (Group/individual).
- Group Discussions on evolution of Indian Agriculture and Development indices.
- Power point presentation by students on policies and their relevance.

IX. Learning outcome

After the completion of the course the student will be able to-Understand the concept of development and its preference over growth. Visualize how the agriculture sector is performing in this aspect. Understand the motive behind the policies and their implementation.

X. Suggested Reading

- Albert O. Hirschman 1958. Strategy of Economic Development. New Man Yale University
- Simon Kuznets 1965. Economic Growth and Structures. Oxford New Delhi.
- Das Gupta AK. 1965. Planning and Economic Growth. George Allen and Unwin London
- Robert E. Baldwin 1966. Economic Development and Growth. John Willey, New York

I. Course Title : Agricultural Finance and Project Management

II. Course Code : AEC 507

III. Credit Hours : 3(2+1)

IV. Why this course?

Money is the fuel of driving all the economic activities. India is a land of small and marginal farmers. The financial conditions of the farmers is not so strong that they can finance themselves. They require credit to meet the requirements of inputs. Thus, the student should know the sources, principles involved and types of credit available. The institutions involved and on what grounds the finance is given to the farmer. What are the risks involved and how to overcome them.

V. Aim of the course

This course is designed with an objective to deliver knowledge of the principles, procedures, problems and policies relating to financing agricultural firms. In addition to this the students are also given knowledge about the research developments in the subject. The approach is analytic.

VI. Organization of the course

The course is organised as follows:

No	Block		Unit
1	Introduction to Agricultural Finance	1.	Basic Concepts: A review
2.	Credit and financial analysis	1.	Credit and its aspects
		2.	Financial analysis
3	Project and risk management	1.	Project Overview
		2.	Risk and its Management

VII. Theory

Block 1: Introduction to Agricultural Finance

Unit 1: Basic concepts: A Review

Role and Importance of Agricultural Finance. Financial Institutions and credit flow to rural/ priority sector. Agricultural lending – Direct and Indirect Financing - Financing through Co-operatives, NABARD and Commercial Banks and RRBs. District Credit Plan and lending to agriculture/priority sector. Micro-Financing and Role of MFI's - NGO's, and SHG's.

Block 2: Credit and Financial Analysis

Unit 1: Credit and its aspects

Lending to farmers – The concept of 3 C's, 7 P's and 3 R's of credit. Estimation of Technical feasibility, Economic viability and repaying capacity of borrowers and appraisal of credit proposals. Understanding lenders and developing better working relationship and supervisory credit system. Credit inclusions – credit widening and credit deepening.

Unit 2: Financial analysis

Financial Decisions – Investment, Financing, Liquidity and Solvency. Preparation of financial statements - Balance Sheet, Cash Flow Statement and Profit and Loss Account. Ratio Analysis and Assessing the performance of farm/ firm.

Block 3- Project and Risk Management

Unit 1: Project Overview

Project Approach in financing agriculture. Financial, economic and environmental appraisal of investment projects. Identification, preparation, appraisal, financing and implementation of projects. Project Appraisal techniques – Undiscounted measures. Time value of money – Use of discounted measures - B-C ratio, NPV and IRR. Agreements, supervision, monitoring and evaluation phases in appraising agricultural investment projects. Net work Techniques – PERT and CPM.

Unit 2: Risk and its Management

Risks in financing agriculture. Risk management strategies and coping mechanism. Crop Insurance programmes – review of different crop insurance schemes - yield loss and weather based insurance and their applications.

VIII. Practical

- Development of Rural Institutional Lending;
- Branch expansion, demand and supply of institutional agricultural credit and Over dues and Loan waiving;
- An overview, Rural Lending Programmes of Commercial Banks, Lead Bank Scheme;
- Preparation of District Credit Plan, Rural Lending Programmes of Co-operative Lending Insti tutions;
- Preparation of financial statements using farm/firm level data, Farm credit appraisal techniques and farm financial analysis through financial statements;
- Performance of Micro Financing Institutions;
- NGO's and Self-Help Groups, Identification and formulation of investment projects;
- Project appraisal techniques – Undiscounted Measures and their limitations;
- Project appraisal techniques – Discounted Measures;
- Network techniques – PERT and CPM for project management;
- Case Study Analysis of an Agricultural project;
- Financial Risk and risk management strategies – crop insurance schemes;
- Financial instruments and methods – E banking, Kisan Cards and core banking.

IX. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions on inflation

X. Learning outcome

After the completion of the course the student will be able to-Understand the key issues of finance in Agriculture. Learn the techniques of assessing the worth of a project.

XI. Suggested Reading

- E Die Sollem H and Heady EO. (Ed.). Capital and Credit Needs in Changing Agriculture, Bauman.
- Hopkins A Barry, Peter Jo and Baker CB. Financial Management in Agriculture.
- Murray WG and Nelson AG. 1960. Agricultural Finance. Iowa State University
- Chanona C. 1969. Agricultural Finance in India: Role of Commercial Banks. Marketing and Economics Research Bureau, New Delhi.
- Gittinger JP. 1972. Economic analysis of agricultural projects, John Hopkins Univ. Press, Balti more.
- Little IMD and JA Mirrless. 1974, Project appraisal and planning for developing countries, Oxford and IBH publishing Co. New Delhi.
- Arnold CH. 1972. Project Evaluation, collected papers, Macmillan.

I. Course Title : Linear Programming

II. Course Code : AEC-508

III. Credit Hours : 2(1+1)

IV. Theory

Unit I

Decision Making- Concepts of decision making, introduction to quantitative tools, introduction to linear programming, uses of LP in different fields, graphic solution to problems, formulation of problems.

Unit II

Simplex Method: Concept of simplex Method, solving profit maximization and cost minimizations problems. Formulation of farms and non farm problems as linear programming models and solutions.

Unit III

Extension of Linear Programming models: Variable resource and price programming, transportation problems, recursive programming, dynamic programming.

Unit IV

Game Theory- Concepts of game theory, two person constant sum, zero sum game, saddle point, solution to mixed strategies, the rectangular game as Linearb Programming.

V. Practical

- Graphical and algebraic formulation of linear programming models.
- Solving of maximization and minimization problems by simplex method.
- Formulation of the simplex matrices for typical farm situations.

I. Course Title : Research Methodology for Social Sciences

II. Course Code : AEC 509

III. Credit Hours : 2(1+1)

IV. Why this course

Planning of research is very crucial to conduct a successful research. There is need to give an insight to the student about how to conduct a research, right from data collection to analysis and finally writing the references.

V. Aim of the course

The course deals with scientific methods of research, the initiation of an inquiry, formulation of research problems and hypotheses, the role of induction and deduction in research, collection and analysis of date and interpretation of results

VI. Organization of the course

The course is organised as follows:

No	Block		Unit
1.	Introduction to research methodology	1.	Concepts of research methodology
2.	Building up hypothesis and sample selection	1. 2.	Hypothesis: Framing and Testing Sampling
3.	Data collection and analysis	1. 2.	Data collection Data Analysis

VII. Theory

Block 1: Concepts of research methodology

Unit 1: Concepts of research methodology

Importance and scope of research in agricultural economics. Types of research - Fundamental vs. Applied. Concept of researchable problem - research prioritization - selection of research problem. Approach to research - research process.

Block 2- Building up hypothesis and sample selection

Unit 1: Hypothesis: Framing and Testing

Hypothesis – meaning – characteristics – types of hypothesis – review of literature – setting of Course Objective and hypotheses – testing of hypothesis.

Unit 2: Sampling

Sampling theory and sampling design – sampling error - methods of sampling – probability and non-probability sampling methods - criteria to choose. Project proposals – contents and scope – different types of projects to meet different needs - trade-off between scope and cost of the study. Research design and techniques - Types of research design.

Block 3- Data Collection and Analysis

Unit 1: Data Collection

Data collection – assessment of data needs – sources of data collection – discussion of different situations. Mailed questionnaire and interview schedule – structured, unstructured, open ended and closed-ended questions. Scaling Techniques. Preparation of schedule – problems in measurement of variables in agriculture. Interviewing techniques and field problems - methods of conducting survey – Reconnaissance survey and Pre testing.

Unit 2: Data Analysis

Data coding, tabulation, cleaning. –Multivariate analysis –factor analysis' PCA' cluster analysis. Universal procedures for preparation of bibliography – writing of research articles.

VIII. Practical

- Exercises in problem identification.
- Project proposals – contents and scope.
- Formulation of Objective and hypotheses.
- Assessment of data needs – sources of data – methods of collection of data.
- Methods of sampling – criteria to choose – discussion on sampling under different situations.
- Scaling Techniques – measurement of scales.
- Preparation of interview schedule.
- Field testing. Method of conducting survey.
- Exercise on coding, editing, tabulation and validation of data.
- Preparing for data entry into computer.
- Hypothesis testing – Parametric and Non-Parametric Tests.
- Exercises on format for Thesis/ Report writing.
- Presentation of the results.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

XI. X. Learning outcome

After the successful completion of this course, student will be able to-Understand fundamentals of research. How to carefully plan out the research work and conduct it.

XII. Suggested Reading

- Baker CB. Research Methodology in Agricultural Economics
- Cohen MR and Nagel R. An Introduction to Logic and Scientific Method

- Devey J Logic. The Theory of Enquiry
- Dhondhyal SP. Social Science Research and Thesis Writing
- Ezekiel M. Correlation Analysis
- Heady EO. Linear Programming Methods
- Willson ER. An Introduction to Scientific Research
- Kumar A. 2008. Research Methodology: A Survey. Alts, New Delhi,

I. Course Title : Indian Economy:History and Contemporary Issues Credit

II. Course Code : AEC-510

III. Credit Hours : 2(2+0)

IV. Why this course?

India is a developing economy. The evolution of the Indian economy will enlighten the student with how an economy develops. Students will understand how the policies and measures taken shape up the economy of the country.

V. Aim of the course

To introduce the students to the economic history over a period of time. It also highlights the contemporary issues of Indian economy.

VI. Organization of the course

The course is organised as follows:

No	Block		Unit
1.	History of Indian Economy	1.	India from Independence to Liberalization
		2. 3.	India since 1980's (Liberalization and Beyond): Overview Macro Trends Since 1990
2.	Contemporary Issues	1.	Contemporary Issues

VII. Theory

Block 1- History of Indian Economy

Unit 1: India from Independence to Liberalization

An overview of the economic developments during the period 1947-1980; Objectives and strategies of planned economic development and the role of the State; Sectoral growth performance; savings and investment; Demographic trends and issues; education; health and malnutrition; Trends and policies in poverty; inequality and unemployment.

Unit 2: India Since 1980's (Liberalization And Beyond): Overview

Policy Changes since 1980s. The 1990 Crisis. Causes and Effects of liberalization. Regional differences: infrastructure, primary, secondary and tertiary sector.

Unit 3: Macro Trends Since 1990

Growth; Savings and Investment, Employment; productivity; diversification; Agro- based industries; competition policy; foreign investment, Regional differences.

Block 2- Contemporary Issues

Unit 1: Contemporary Issues

Monetary and Financial trends- areas of government spending in India, Capital expenditure, revenue expenditure, plan expenditure, non plan expenditure, Deficits (fiscal, primary, revenue), impact of fiscal deficit on economy, Capital receipts, revenue receipts, tax and non tax revenue, direct and indirect taxes, need to rationalize taxstructure. Goods and Services Tax (GST). Union Budget, Zero base budgeting, Gender budgeting, Fiscal devolution and centre state financial relations in India, WPI, CPI implicit deflators. Foreign Trade policy.

VIII. Teaching Methods/ Activities

- Lectures
- Power point presentation by students on monetary and fiscal policy in past and present.
- Assignments (Group/individual).
- Group Discussions on Tax and its reforms.

IX. Learning outcome

After the completion of the course the student will be able to-Visualize how the Indian economy has evolved. Get acquainted with the basic steps involved in the working of the national economy.

X. Suggested Reading

- *Dutt and Sundaram. Indian Economy*

I. Course Title : International Economics

II. Course Code : AEC 511

III. Credit Hours : 2(1+1)

IV. Why this course?

The era of Globalisation, liberalization and privatization has unified the whole world. There is trade across national boundaries and one economy has effect on the other. Getting familiar with national economy is not sufficient to understand the mechanism of trade and economic aspects. Thus, this course is designed to teach student about the trade as international level.

V. Aim of the course

The major objective of this course is to give an insight of the interactions between national economies. What are the theories governing the trade across national boundaries. The methods involved to regulate the international trade and institutions involved.

VI. Organization of the course

The course is organised as follows:

No	Block		Unit
1.	Introduction	1.	Concepts of International Economics
2.	Models, Rate and terms of trade	1.	Barriers to trade
		2.	Models of trade
		3.	Rates and Terms of trade
3	Institutions	1.	Trades Institutions

VII. Theory

Block 1- Introduction

Unit 1: Concepts of International Economics

Scope and Significance of International Economics – The role of trade- General Equilibrium in a Closed Economy (Autarky Equilibrium) – Equilibrium in a Simple Open Economy - Possibility of World Trade - Trade gains and Trade Equilibrium.

Block 2- Models, Rate and Terms of Trade

Unit 1: Barriers to trade

Tariff, Producer Subsidy, Export Subsidy, Import Quota and Export Voluntary Restraints- The Case of Small Country and Large Country Case.

Unit 2: Models of trade

Ricardian Model of Trade- Specific Factors Model- Heckscher - Ohlin Model - Trade Creation and Trade Diversion – Offer Curve - Export Supply Elasticity and Import Demand Elasticity – Comparative Advantage and Absolute Advantage.

Unit 3: Rates and Terms of trade

Official Exchange Rate and Shadow Exchange Rate - Walra's Law and Terms of Trade – Trade Blocks.

Block 3- Institutions

Unit 1: Trades Institutions

IMF, World Bank, IDA, IFC, ADB – International Trade agreements – Uruguay Round – GATT – WTO.

VIII. Practical

- Producer's Surplus, Consumer's Surplus, National Welfare under Autarky and Free Trade Equi librium with small and large country assumption.
- Estimation of Trade Gains
- Estimation of competitive and comparative measures like NPC, EPC, ERP and DRC
- Estimation of Offer Curve Elasticity
- Estimation of Effect of Tariff, Export Subsidy, Producer Subsidy, Import Quota and Export

Voluntary Restraints on National Welfare

- Estimation of Ricardian Model
- Estimation of Effect of Trade under Specific Factor Model
- Estimation of trade Equilibrium under Heckscher -Ohlin model
- Trade Creation and Diversion.

X. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Power point presentation on International Trade in current scenario.

XI. Learning outcome

After successful completion of the course the student will be able to –Understand how trade take place between nations. Be able to work out strategies to maintain a favourable trade balance. Understand how the institutions play role in regulating the cross country trade and deal with the issues.

XII. Suggested Reading

- Kindelberger and Joshi PK. 2016. International Economics AITBS Delhi-110051
- Brouwer F. International Trade and Food Security. LEI - Wageningen UR, The Netherlands.

Agricultural Meteorology

Course Title with Credit Load
M.Sc. in Agriculture Meteorology

Course Code	Course Title	Credit Hours
AGM 501	Fundamentals of Meteorology	3(2+1)
AGM 502	Fundamentals of Agricultural Meteorology	3(2+1)
AGM 503	Crop-weather Relationships	2(2+0)
AGM 504	Agro-meteorological Measurements and Instrumentation	3(1+2)
AGM 505	Crop Micrometeorology	3(2+1)
AGM 506	Evapotranspiration and Soil Water Balance	3(2+1)
AGM 507	Crop weather models	3(1+2)
AGM 508	Applied Agricultural Climatology	3(1+2)
AGM 509	Weather forecasting	3(2+1)
AGM 510	RS and GIS Applications in Agricultural Meteorology	3(2+1)
AGM 511	Strategic use of climatic information	3(2+1)
AGM 512	Weather and climate risk management	2(2+0)
AGM 513	Aerobiometeorology	3(2+1)

Course Contents
M.Sc. in Agriculture Meteorology

I. Course Title : Fundamentals of Meteorology

II. Course Code : AGM 501

III. Credit Hours : 3(2+1)

IV. Aim of the course

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

V. Theory Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

VI. Practical

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

VII. Teaching Methods/ Activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

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

IX. Suggested Reading

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

Journals

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

Websites

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

I. Course Title : Fundamentals of Agricultural Meteorology
II. Course Code : AGM 502
III. Credit Hours : 3(2+1)
IV. Aim of the course

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

V. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

VI. Practical

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

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Overall and basic knowledge on Agrometeorology

IX. Suggested Reading

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

Journals

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

Websites

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

I. Course Title : Crop-weather Relationships
II. Course Code : AGM 503
III. Credit Hours : 2(2+0)
IV. Aim of the course

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

V. Theory

Unit I

Understanding the influence of weather elements on crop growth, impact of climatic Variability and eXtremes on crop production, climatic normals for crop production.

Unit II

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

Unit III

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

Unit IV

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

VI. Teaching methods/activities

Classroom teaching

VII. Learning outcome

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

VIII. Suggested Reading

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

Journals

- Journal of Agrometeorology
- Agricultural and Forest Meteorology

Websites

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

I. Course Title : Agro-meteorological Measurements and Instrumentation

II. Course Code : AGM 504

III. Credit Hours : 3(1+2)

IV. Aim of the course

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

V. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Unit VI

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

VI. Practical

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

VII. Teaching methods/activities

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

VIII.Learning outcome

Practical classes and theory

IX. Suggested Reading

- Anonymous. 1987. Instructions to Observers at Surface Observatories. Part I, IMD, New Delhi.
- Byers HR. 1959. General Meteorology. McGraw Hill.
- Ghadekar SR. 2002. Practical Meteorology: Data Acquisition Techniques, Instruments and Methods. Agromet Publ.
- Middleton WE and Spilhaws AF. 1962. Meteorological Department. University of Toronto Press.
- Tanner CB. 1973. Basic Instrumentation and Measurements for Plant Environment and Micrometeology. University of Wisconsin, Madison.
- WMO. 2008. Guide to Meteorological Instruments and Methods of Observation. WMO-No.8

Journals

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

Website

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

I. Course Title : Crop Micrometeorology
II. Course Code : AGM 505
III. Credit Hours : 3(2+1)
IV. Aim of the course

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

V. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

VI. Practical

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

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

Knowledge of microclimatic conditions governing crop growth

IX. Suggested Reading

- Pal AS. 1988. Introduction to Micrometeorology. Academic Press.
- Bishnoi OP. 2007. Principles of Agricultural Meteorology. Oxford Book Co.
- Chang, Jen-Hu. 1968. Climate and Agriculture: An Ecological Survey. Aldine Publishing Company.
- Gates DM. 1968. Energy Exchange in the Biosphere. UNESCO.
- Goudriaan J. 1983. Crop Micrometeorology: A Simulation Study. Scientific Publ.
- Grace J. 1983. Plant Atmospheric Relationships: Outline Studies in Ecology. Chapman & Hall.
- Gupta PL and Rao VUM. 2000. Practical Manual on Micrometeorology. Dept. of Agril. Meteorology, CCS HAU Hisar, India.
- Jones HG. 1992. Plants and Microclimate. Cambridge Univ. Press. Munn RE. 1970. Biometeorological Methods. Academic Press.

- Monteith and Unsworth. 2013. Principles of Environmental Physics. Elsevier.
- Rosenberg NJ. 1974. Microclimate – The biological Environmet. John Wiley & Sons.
- Sellers W. 1967. Physical Climatology. The University of Chicago Press.

Journals

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

Website

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

I. Course Title : Evapotranspiration and Soil Water Balance
II. Course Code : AGM 506
III. Credit Hours : 3(2+1)
IV. Aim of the course

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

V. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

VI. Practical

- Measurement of various components of soil water balance
- Evaluation of hydraulic conductivity vs. soil moisture relationship by water balance approach
- Computation and comparison of evapotranspiration by different methods - energy balance method,

aerodynamic method, Penman method, remote sensing and other methods

- Soil moisture retention characteristics by pressure plate method.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

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

IX. Suggested Reading

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

Journals

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

Websites

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

I. Course Title : Crop Weather Models
II. Course Code : AGM 507
III. Credit Hours : 3(1+2)
IV. Aim of the course

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

V. Theory

Unit I

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

Unit II

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

Unit III

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

VI. Practical

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

VII. Teaching methods/activities

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

VIII. Learning outcome

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

IX. Suggested Reading

- Wallach Det al. Working with dynamic crop models.
- DeWit CT, Brouwer R and de Vries FWTP. 1970. The Simulation of Photosynthetic Systems. pp. 7-70. In. Prediction and Measurement of Photosynhetic Activity. Proc. Int. Biological Programme Plant Physiology Tech. Meeting Trebon PUDOC. Wageningen.
- Duncan WG. 1973. SIMAI- A Model Simulating Growth and Yield in Corn. In: The Application of Systems Methods to Crop Production (D.N. Baker, Ed.). Mississippi State Univ. Mississipi.
- Frere M and Popav G. 1979. Agrometeorological Crop Monitoring and Forecasting. FAO.
- Hanks RJ. 1974. Model for Predicting Plant Yield as Influenced by Water Use. Agron. J. 66: 660-665.
- Hay RKM and Porter JR. 2006. The physiology of crop yield (2nd Edition).
- Keulen H Van and Seligman NG. 1986. Simulation of Water Use, Nitrogen Nutrition and Growth of a Spring Wheat Crop. Simulation Monographs. PUDOC, Wageningen.
- Singh P. Modelling of crop production systems: Principles and applications.
- WeiXing Cao et al. Crop modeling and decision support.

Journals

- Journal of Agrometeorology
- Global Environmental Change

- Global Change Biology
- Mitigation and Adaptation Strategies for Global Change

Websites

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

I. Course Title : Applied Agricultural Climatology

II. Course Code : AGM 508

III. Credit Hours : 3(1+2)

IV. Aim of the course

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

V. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

VI. Practical

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

VII. Teaching methods/activities

Theory and practical classes

VIII. Teaching methods/activities

Knowledge on how to use the meteorological observations and derived indices are applied in agricultural field

IX. Suggested Reading

- Anonymous 1980. ICRISAT Climatic Classification – A Consultation Meeting. ICRISAT.
- Bishnoi OP. 2007. Principles of Agricultural Meteorology. Oxford Book Co.
- Lal DS. 1989. Climatology. Chaitanya Publ. House.
- Mather JR. 1977. Work Book in Applied Climatology. Univ. of Delware, New Jersey.
- Mavi HS and Tupper Graeme J. 2004. Agrometeorology: Principles and Applications of Climate Studies in Agriculture. The Haworth Press.
- Stigter K (Ed.). 2010. Applied Agrometeorology. Springer
- Subramaniam VP. 1977. Incidence and Spread of Continental Drought. WMO/IMD Report No. 2, WMO, Geneva, Switzerland.
- Thompson R. 1997. Applied Climatology: Principles and Practice. Routledge.
- Walter J Saucier. 2003. Principles of Meteorological Analysis. Dover PhoeniX Eds.

Journals

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

Websites

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

I. Course Title : Weather Forecasting

II. Course Code : AGM 509

III. Credit Hours : 3(2+1)

IV. Aim of the course

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

V. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

I. Practical

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

II. Teaching methods/ activities

Theory and practical classes

III. Learning outcome

Enhancing knowledge on weather forecast and its use

IV. Suggested Reading

- Watts A. 2005. Instant Weather Forecasting. Water Craft Books.
- Ram Sastry AA. 1984. Weather and Weather Forecasting. Publication Division, GOI, New Delhi.
- Singh SV, Rathore LS and Trivedi HKN. 1999. A Guide for Agrometeorological Advisory Services. Department of Science and Technology, NCMRWF, New Delhi.
- Wegman and Depriest. 1980. Statistical Analysis of Weather Modification Experiments. Amazon Book Co.

Journals

- Journal of Climatology and Weather Forecasting
- Theoretical and Applied Climatology
- Atmospheric Research Journal
- Journal of Agrometeorology
- Agroclimatology

Websites

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

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

II. Course Code : AGM 510

III. Credit Hours : 3(2+1)

IV. Aim of the course

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

V. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Unit VI

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

Unit VII

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

VI. Practical

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

VII. Teaching methods/activities

Hands on practicals and theory

VIII. Learning outcome

Knowledge on RS-GIS technique for application in Agricultural Meteorology

IX. Suggested reading

- Bishnoi OP. 2007. Principles of Agricultural Meteorology. Oxford Book Co.
- Campbell JB. 1996. Introduction to Remote Sensing, 2nd ed., The Guilford Press, New York.
- Colwell RN. (Ed.). Manual of Remote Sensing. Vols. 1, II. Am. Soc. Photogrammetry, Virginia.
- Curan PJ. Principles of Remote Sensing. ELBS/Longman.
- Georg Joseph 2005.Fundamentals of Remote Sensing. University Press (India).
- Jain AK. 1989. Fundamentals of Digital Image Processing, Prentice Hall of India.
- Lilisand TM, Kiefer RW and Chipman JW. 2003. Remote Sensing and Image Interpretation, 5th ed., John Wiley & Sons, Inc., New York.
- Narayan LRA. 1999. Remote Sensing and its Applications. Oscar Publ.
- Panda BC. 2008. Principles and Applications of Remote Sensing, Viva Publications.
- Patel AN and Surender Singh. 2004. Remote Sensing: Principles and Applications. Scientific Publ.

Journals

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

Websites

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

I. Course Title : Strategic Use of Climatic Information

II. Course Code : AGM 514

III. Credit Hours : 3(2+1)

IV. Aim of the course

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

V. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Unit VI

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

Practical

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

VI. Teaching methods/activities

Theory and practical classes

VII. Learning outcome

Application of climatic information for agriculture and natural resource management

VIII. Suggested Reading

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

Journals

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

Website:

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

I. Course Title : Weather and Climate Risk Management

II. Course Code : AGM 515

III. Credit Hours : 2(2+0)

IV. Aim of the course

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

V. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Unit VI

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

Unit VII

Challenges to coping strategies-combining challenges to disaster risk mainstreaming, mitigation practices, contingency planning and responses, basic preparedness; preparedness approaches reducing emergency relief necessities; the role that insurances can play in risk spreading and transfer; application of methods that permit the incorporation of seasonal and long-term forecasts into the risk assessment models.

VI. Teaching methods/ activities

Theory classes

VII. Learning outcome

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

VIII. Suggested Reading

- Anonymous 2003. Critical Issues in Weather Modification Research Board of Atmoshperic Science and Climate. National Research Council, USA.
- Bishnoi OP. 2007. Principles of Agricultural Meteorology. Oxford Book Co.
- Chritchfield HJ. 1994. General Climatology. Prentice Hall.

- Lenka D. 1998. Climate, Weather and Crops in India. Kalyani.
- Mavi HS and Graeme J Tupper. 2004. Agrometeorology: Principles and Applications of Climate Studies in Agriculture. The Haworth Press.
- Mavi HS. 1994. Introduction to Agrometeorology. OXford & IBH.
- Menon PA. 1989. Our Weather. National Book Trust.
- Pearce RP. 2002. Meteorology at the Millennium. Academic Press.
- Rosenberg NJ, Blad BL and Verma SB. 1983. Microclimate – The Biological Environment. John Wiley & Sons.
- Samra JS, Narain P, Rattan RK and Singh SK. 2006. Drought Management in India. Bull. Indian Society of Soil Science 24, ISSS, New Delhi.

Journals

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

Website

- https://www.icrisat.org/

I. Course Title : Aerobiometeorology

II. Course Code : AGM 516

III. Credit Hours : 3(2+1)

IV. Aim of the course

To impart theoretical knowledge on insect, pest and plant biometeorology

V. Theory

Unit I

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

Unit II

Benevolent and malevolent weather conditions for salient pests & diseases of the concerned agro-climatic zones. Effects of sudden weather changes and extreme weather conditions on population built-up of the pest, heat stress and heat related mortality, climate change impact on pest and diseases.

Unit III

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

Unit IV

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

VI. Practical

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

VII. Teaching methods/activities

Classroom teaching and practical, visit to fields

VIII. Learning outcome

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

IX. Suggested Reading

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

Journals

- Aerobiologica
- Journal of Agrometeorology
- International Journal of Biometeorology

Website

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

AGRICULTURAL STATISTICS

Course Title with Credit Load

M.Sc. (Agri.) in Agricultural Statistics

Course Code	Course Title	Credit Hours
STAT 552	Probability Theory	2+0
STAT 553	Statistical Methods	2+1
STAT 562	Statistical Inference	2+1
STAT 563	Design of Experiments	2+1
STAT 564	Sampling Techniques	2+1
STAT 565	Statistical Genetics	2+1
STAT 571	Multivariate Analysis	2+1
STAT 572	Regression Analysis	1+1
STAT 573	Statistical Computing	1+1
STAT 551	Mathematics-I	3+0
STAT 554	Actuarial Statistics	2+0
STAT 555	Bioinformatics	2+0
STAT 556	Econometrics	2+0
STAT 561	Mathematics-II	2+0
STAT 566	Statistical Quality Control	2+0
STAT 567	Optimization Techniques	1+1
STAT 574	Time Series Analysis	1+1
STAT 575	Demography	2+0
STAT 576	Statistical Methods for Life Sciences	2+0
STAT 577	Statistical Ecology	2+0

Course Title
M.Sc. (Agri.) in Agricultural Statistics

I. Course Title : Probability Theory

II. Course Code : STAT 552

III. Credit Hours : 2(2+0)

IV. Aim of the course

This is a fundamental course in Statistics. This course lays the foundation of probability theory, random variable, probability distribution, mathematical expectation, etc. which forms the basis of basic statistics. The students are also exposed to law of large numbers and central limit theorem. The students also get introduced to stochastic processes.

V. Theory

Unit I

Basic concepts of probability. Elements of measure theory: class of sets, field, sigma field, minimal sigma field, Borel sigma field in R, measure- probability measure. Axiomatic approach to probability. Properties of probability based on axiomatic definition. Addition and multiplication theorems. Conditional probability and independence of events. Bayes theorem.

Unit II

Random variables: definition of random variable, discrete and continuous, functions of random variables. Probability mass function and Probability density function, Distribution function and its properties. Notion of bivariate random variables, bivariate distribution function and its properties. Joint, marginal and conditional distributions. Independence of random variables. Transformation of random variables (two dimensional caseonly). Mathematical expectation: Mathematical expectation of functions of a random variable. Raw and central moments and their relation, covariance, skewness and kurtosis. Addition and multiplication theorems of expectation. Definition of moment generating function, cumulating generating function, probability generating function and statements of their properties.

Unit III

Conditional expectation and conditional variance. Characteristic function and its properties. Inversion and uniqueness theorems. Chebyshev, Markov, Cauchy- Schwartz, Sequence of random variables and modes of convergence (convergence in distribution in probability, almost surely, and quadratic mean) and their interrelations.

Unit IV

Laws of large numbers: WLLN, Bernoulli and Kintchin's WLLN. Kolmogorov inequality, Kolmogorov's SLLNs.Central Limit theorems: Demoviere- Laplace CLT, Lindberg – Levy CLT and simple applications.

VI. Suggested Reading

- Ash RB. 2000. Probability and Measure Theory. 2nd Ed. Academic Press. Billingsley P. 1986. Probability and Measure. 2nd Ed. John Wiley.
- Capinski M and Zastawniah. 2001. Probability Through Problems. Springer. Dudewicz EJ & Mishra SN. 1988. Modern Mathematical Statistics. John Wiley.

- Feller W. 1972. An Introduction to Probability Theory and its Applications. Vols. I., II. John Wiley.
- Loeve M. 1978. Probability Theory. 4th Ed. Springer.
- Marek C, Tomasz JZ. 2003. Probability Through Problems (Problem Books in Mathematics) Corrected Ed.
- Marek F. 1963. Probability Theory and Mathematical Statistics. John Wiley.
- Rohatgi VK & Saleh AK Md. E. 2005. An Introduction to Probability and Statistics. 2nd Ed. John Wiley.

I. Course Title : Statistical Methods

II. Course Code : STAT 553

III. Credit Hours : 3(2+1)

IV. Aim of the course

This course lays the foundation of probability distributions and sampling distributions and their application which forms the basis of Statistical Inference. Together with probability theory, this course is fundamental to the discipline of Statistics. The students are also exposed to correlation and regression, and order statistics and their distributions. Categorical data analysis is also covered in this course.

V. Theory

Unit I

Descriptive statistics: probability distributions: Discrete probability distributions ~ Bernoulli, Binomial, Poisson, Negative-binomial, Geometric and Hyper Geometric, uniform, multinomial ~ Properties of these distributions and real life examples. Continuous probability distributions ~ rectangular, exponential, Cauchy, normal, gamma, beta of two kinds, Weibull, lognormal, logistic, Pareto. Properties of these distributions. Probability distributions of functions of random variables.

Unit II

Concepts of compound, truncated and mixture distributions (definitions and examples). Sampling distributions of sample mean and sample variance from Normal population, central and non–central chi-Square, t and F distributions, their properties and inter relationships.

Unit III

Concepts of random vectors, moments and their distributions. Bivariate Normal distribution - marginal and conditional distributions. Distribution of quadratic forms. Cochran theorem. Correlation, rank correlation, correlation ratio and intra-class correlation. Regression analysis, partial and multiple correlation and regression.

Unit IV

Sampling distribution of correlation coefficient, regression coefficient. Categorical data analysis, Association between attributes. Variance StabilizingTransformations.

Unit V

Order statistics, distribution of r-th order statistics, joint distribution of several order statistics and their functions, marginal distributions of order statistics.

VI. Practical

- Fitting of discrete distributions and test for goodness of fit;
- Fitting of continuous distributions and test for goodness of fit; Fitting of truncated distribution;
- Computation of simple, multiple and partial correlation coefficient, correlation ratio and intra-class correlation;
- Regression coefficients and regression equations;
- Fitting of Pearsonian curves;
- Analysis of association between attributes, categorical data and log-linear models.

VII. Suggested Reading

- Agresti, A. 2012. Categorical Data Analysis 3rd Ed. John Wiley.
- Arnold BC, Balakrishnan N and Nagaraja HN. 1992. A First Course in Order Statistics. JohnWiley.
- David HA and Nagaraja HN. 2003. Order Statistics. 3rd Ed. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. Modern Mathematical Statistics. John Wiley.
- Huber PJ. 1981. Robust Statistics. John Wiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. Continuous Univariate Distributions. JohnWiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. Discrete Univariate Distributions. JohnWiley.
- Marek F.1963. Probability Theory and Mathematical Statistics. John Wiley.
- Rao CR. 1965. Linear Statistical Inference and its Applications. John Wiley.
- Rohatgi VK and Saleh AK Md. E. 2005. An Introduction to Probability and Statistics. 2nd Ed. John Wiley.
- Gupta. S.P 2008. Statistical Methods. Sultan Chand & sons Educational Publisher

I. Course Title : Actuarial Statistics

II. Course Code : STAT 554

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant to expose to the students to the statistical techniques such as probability models, life tables, insurance and annuities. The students would also be exposed top practical applications of these techniques in computation of premiums that include expenses, general expenses, types of expenses and per policy expenses.

V. Theory

Unit I

Insurance and utility theory, models for individual claims and their sums, survival function, curtate future lifetime, force of mortality.

Unit II

Life table and its relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables.

Unit III

Multiple life functions, joint life and last survivor status, insurance and annuity benefits through multiple life functions evaluation for special mortality laws. Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrement, net single premiums and their numerical evaluations.

Unit IV

Distribution of aggregate claims, compound Poisson distribution and its applications.

Unit V

Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding.

Unit VI

Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance, recursions, commutation functions.

Unit VII

Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions, varying annuities, recursions, complete annuities-immediate and apportionable annuities-due.

Unit VIII

Net premiums: Continuous and discrete premiums, true monthly payment premiums, apportionable premiums, commutation functions, accumulation type benefits. Payment premiums, apportionable premiums, commutation functions, accumulation type benefits. Net premium reserves: Continuous and discrete net premium reserve, reserves on a semi-continuous basis, reserves based on true monthly premiums, reserves on an apportionable or discounted continuous basis, reserves at fractional durations, allocations of loss to policy years, recursive formulas and differential equations for reserves, commutation functions.

Unit IX

Some practical considerations: Premiums that include expenses-general expenses types of expenses, per policy expenses. Claim amount distributions, approximating the individual model, stop-loss insurance.

VI. Suggested Reading

- Atkinson ME and Dickson DCM. 2000. An Introduction to Actuarial Studies. Elgar Publ.
- Bedford T and Cooke R. 2001. Probabilistic Risk Analysis. Cambridge.
- Booth PM, Chadburn RG, Cooper DR, Haberman, S and James DE.1999. Modern Actuarial Theory and Practice. Chapman & Hall.
- Borowiak Dale S. 2003. Financial and Actuarial Statistics: An Introduction. Marcel Dekker.
- Bowers NL, Gerber HU, Hickman JC, Jones DA and Nesbitt CJ.1997. Actuarial Mathematics. 2nd Ed. Society of Actuaries, Ithaca, Illinois.
- Dale SB, Arnold FS. 2013. Financial and Actuarial Statistics: An Introduction, 2nd Ed. (Statistics: A Series of TeXtbooks and Monogrphs)

- Daykin CD, Pentikainen T and Pesonen M. 1994. Practical Risk Theory for Actuaries. Chapman & Hall.
- Klugman SA, Panjer HH, Willmotand GE and Venter GG. 1998. Loss Models: From data to Decisions. John Wiley.
- Medina PK and Merino S. 2003. Mathematical Finance and Probability: A Discrete Introduction. Basel, Birkhauser.
- Melnikov, A. 2011. Risk Analysis in Finance and Insurance (Chapman & Hall/Crc Financial Mathematics Series) 2nd Ed.
- Neill A. 1977. Life Contingencies. Butterworth-Heinemann.
- Rolski T, Schmidli H, Schmidt V and Teugels J. 1998. Stochastic Processes for Insurance and Finance. John Wiley.
- Rotar VI. 2006. Actuarial Models. The Mathematics of Insurance. Chapman& Hall/CRC.
- Spurgeon ET. 1972. Life Contingencies. Cambridge Univ. Press.

I. Course Title : Bioinformatics

II. Course Code : STAT 555

III. Credit Hours : 2(2+0)

IV. Aim of the course

Bioinformatics is a new emerging area. It is an integration of Statistics, Computer applications and Biology. The trained manpower in the area of Bioinformatics is required for meeting the new challenges in teaching and research in the discipline of Agricultural Sciences. This course is meant to train the students on concepts of basic biology, statistical techniques and computational techniques for understanding bioinformatics principals.

V. Theory

Unit I

Basic Biology: Cell, genes, gene structures, gene expression and regulation, Molecular tools, nucleotides, nucleic acids, markers, proteins and enzymes, bioenergetics, single nucleotide polymorphism, expressed sequence tag. Structural and functional genomics: Organization and structure of genomes, genome mapping, assembling of physical maps, strategies and techniques for genome sequencing and analysis.

Unit II

Computing techniques: OS and Programming Languages – Linux, perl, bioperl,python, biopython,cgi, MySQL, phpMyAdmin; Coding for browsing biological databases on web, parsing & annotation of genomic sequences; Database designing; Computer networks – Internet, World wide web, Web browsers– EMBnet, NCBI; Databases on public domain pertaining to Nucleic acid sequences, protein sequences, SNPs, etc.; Searching sequence databases, Structural databases.

Unit III

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

Unit IV

Tools for Bioinformatics: DNA Sequence Analysis – Features of DNA sequence analysis, Approaches to EST analysis; Pairwise alignment techniques: Comparing two sequences, PAM and BLOSUM, Global alignment (The Needleman and Wunsch algorithm), Local Alignment (The Smith-Waterman algorithm), Dynamic programming, Pairwise database searching; Sequence analysis– BLAST and other related tools, Multiple alignment and database search using motif models, ClustalW, Phylogeny; Databases on SNPs; EM algorithm and other methods to discover common motifs in biosequences; Gene prediction based on Neural Networks, Genetic algorithms, Computational analysis of protein sequence, structure and function; Design and Analysis of microarray/ RNAseqexperiments.

VI. Suggested Reading

- Baldi P. and Brunak S. 2001. Bioinformatics: The Machine Learning Approach. 2nd Ed. (Adap tive Computation and Machine Learning). MIT Press.
- Baxevanis A.D. and Francis B.F. (Eds.). 2004. Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins. John Wiley
- Bergeron B.P. 2002. Bioinformatics Computing. Prentice Hall.
- Duda R.O, Hart P.E and Stork D.G. 1999. Pattern Classification. John Wiley.
- Ewens W.J and Grant G.R. 2001. Statistical Methods in Bioinformatics: An Introduction (Sta tistics for Biology and Health). Springer.
- Graham B. Zweig, J. Buffett, WE. 2006.The Intelligent Investor: The Definitive Book on Value Investing. A Book of Practical Counsel, Revised Edition
- Hunt S and Livesy F. (Eds.). 2000. Functional Genomics: A Practical Approach (The Practical Approach Series, 235). OXford Univ. Press.
- Jones N.C. and Pevzner P.A. 2004. An Introduction to Bioinformatics Algorithims. MIT Press.
- Koski T and Koskinen T. 2001. Hidden Markov Models for Bioinformatics. Kluwer.
- Krane D.E. and Raymer M.L. 2002. Fundamental Concepts of Bio-informatics. Benjamin / Cummings.
- Krawetz S.A and Womble D.D. 2003. Introduction to Bioinformatics: A Theoretical and Prac tical Approach. Humana Press.
- Lesk A.M. 2002. Introduction to Bio-informatics. Oxford Univ. Press.
- Percus J.K. 2001. Mathematics of Genome Analysis. Cambridge Univ. Press.
- Sorensen D and Gianola D. 2002. Likelihood, Bayesian and MCMC Methods in Genetics. Springer.
- Tisdall J.D. 2001. Mastering Perl for Bioinformatics. O'Reilly & Associates.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. Data Mining in Bioinformatics. Springer.
- Wu C.H. and McLarty J.W. 2000. Neural Networks and Genome Informatics. Elsevier.
- Wunschiers R. 2004. Computational Biology Unix/Linux, Data Processing and Programming. Springer.

I. Course Title : Econometrics
II. Course Code : STAT 556
III. Credit Hours : 2(2+0)
IV. Aim of the course

This course is meant for training the students in econometric methods and their applications in agriculture. This course would enable the students in understanding the economic phenomena through statistical tools and economics principles.

V. Theory

Unit I

Representation of Economic phenomenon, relationship among economic variables, linear and non-linear economic models, single equation general linear regression model, basic assumptions, Ordinary least squares method of estimation for simple and multiple regression models; summary statistics correlation matrix, co-efficient of multiple determination, standard errors of estimated parameters, tests of significance and confidence interval estimation. BLUE properties of Least Squares estimates. Chow test, test of improvement of fit through additional regressors. Maximum likelihood estimation.

Unit II

Heteroscedasticity, Auto-correlation, Durbin Watson test, Multi-collinearity. Stochastic regressors, Errors in variables, Use of instrumental variables in regression analysis. Dummy Variables. Distributed Lag models: Koyck's Geometric Lag scheme, Adaptive Expectation and Partial Adjustment Mode, Rational Expectation Models and test for rationality.

Unit III

Simultaneous equation model: Basic rationale, Consequences of simultaneous relations, Identification problem, Conditions of Identification, Indirect Least Squares, Two-stage least squares, K-class estimators, Limited Information and Full Information Maximum Likelihood Methods, three stage least squares, Generalized least squares, Recursive models, SURE Models. Mixed Estimation Methods, use of instrumental variables, pooling of cross-section and time series data, Principal Component Methods.

Unit IV

Problem and Construction of index numbers and their tests; fixed and chain based index numbers; Construction of cost of living index number.

Unit V

Demand analysis – Demand and Supply Curves; Determination of demand curves from market data. Engel's Law and the Engel's Curves, Income distribution and method of its estimation, Pareto's Curve, Income inequality measures.

VI. Suggested Reading

- Croxton F.E. and Cowden D.J. 1979. Applied General Statistics. Prentice Hall of India.
- James H.S. and Mark W.W. 2017. Introduction to Econometrics, 3rd Ed. John Wiley
- Johnston J. 1984. Econometric Methods. McGraw Hill.
- Judge G.C., Hill R.C., Griffiths W.E., Lutkepohl H and Lee T.C. 1988. Introduction to the Theory and Practice of Econometrics. 2nd Ed. John Wiley.

- Kmenta J. 1986. Elements of Econometrics. 2nd Ed. University of Michigan Press.
- Koop G. 2007. Introduction to Econometrics. John Wiley.
- Maddala G.S. 2001. Introduction to Econometrics. 3rd Ed. John Wiley.
- Pindyck R.S. and Rubinfeld D.L. 1998. Econometric Models and Economic Forecasts. 4th Ed. McGraw Hill.
- Verbeek M. 2008. A Guide to Modern Econometrics. 3rd Ed. John Wiley.

I. Course Title : Mathematics-II

II. Course Code : STAT 561

III. Credit Hours : 2(2+0)

IV. Aim of the course

This is another course that supports all other courses in Agricultural Statistics. The students would be exposed to the advances in Linear Algebra and Matrix theory. This would prepare them to study their main courses that involve knowledge of Linear Algebra and Matrix Algebra.

V. Theory

Unit I

Linear Algebra: Group, ring, field and vector spaces, Sub-spaces, basis, Gram Schmidt's orthogonalization, Galois field - Fermat's theorem and primitive elements. Linear transformations. Graph theory: Concepts and applications.

Unit II

Matrix Algebra: Basic terminology, linear independence and dependence of vectors. Row and column spaces, Echelon form. Determinants, Trace of matrices rank and inverse of matrices. Special matrices – idempotent, symmetric, orthogonal. Eigen values and eigen vectors, Spectral decomposition of matrices.

Unit III

Unitary, Similar, Hadamard, Circulant, Helmert's matrices. Kronecker and Hadamard product of matrices, Kronecker sum of matrices. Sub-matrices and partitioned matrices, Permutation matrices, full rank factorization, Grammian rootof a symmetric solutions.

Unit IV

Solutions of linear equations, Equations having many Generalized inverses, Moore-Penrose inverse, Applications of g-inverse. Inverse and Generalized inverse of partitioned matrices, Differentiation and integration of vectors and matrices, Quadratic forms.

VI. Suggested Reading

- Aschbacher M. 2000. Finite Group Theory. Cambridge University Press.
- Deo N. 1984. Graph Theory with Application to Engineering and Computer Science. Prentice Hall of India.
- Gentle JE. 2007. Matrix Algebra: Theory, Computations and Applications in Statistics. Springer.
- Graybill FE.1961. Introduction to Matrices with Applications in Statistics. Wadsworth Publ.
- Hadley G. 1969. Linear Algebra. Addison Wesley.

- Harville DA. 1997. Matrix Algebra from a Statistician's Perspective. Springer.
- Rao CR. 1965. Linear Statistical Inference and its Applications. 2nd Ed. John Wiley.
- Robinson DJS. 1991. A Course in Linear Algebra with Applications. World Scientific.
- Searle SR. 2006. Matrix Algebra Useful for Statistics John Wiley, 2nd Ed.
- Seber GAF. 2008. A Matrix Handbook for Statisticians. John Wiley.

I. Course Title : Statistical Inference

II. Course Code : STAT 562

III. Credit Hours : 3(2+1)

IV. Aim of the course

This course lays the foundation of Statistical Inference. The students would be taught the problems related to point and confidence interval estimation and testing of hypothesis. They would also be given the concepts of nonparametric and sequential test procedures and elements of decision theory.

V. Theory

Unit I

Concepts of point estimation: unbiasedness, consistency, efficiency and sufficiency. Statement of Neyman's Factorization theorem with applications. MVUE, Rao- Blackwell theorem, completeness, Lehmann- Scheffe theorem. Fisher information, Cramer-Rao lower bound and its applications.

Unit II

Moments, minimum chi-square, least square and maximum likelihood methods of estimation and theirproperties.Interval estimation-Confidence level, shortest lengthCI. CI for the parameters of Normal, Exponential Binomial and Poisson distributions.

Unit III

Fundamentals of hypothesis testing-statistical hypothesis, statistical test, critical region, types of errors, test function, randomized and non- randomized tests, level of significance, power function, most powerful tests: Neyman-Pearson fundamental lemma, MLR families and UMP tests for one parameter exponential families.

Concepts of consistency, unbiasedness and invariance of tests. Likelihood Ratio tests, asymptotic properties of LR tests with applications (including homogeneity of means and variances).Relation between confidence interval estimation and testing of hypothesis.

Unit IV

Sequential Probability ratio test, Properties of SPRT.Termination property of SPRT, SPRT for Binomial, Poisson, Normal and Exponential distributions. Concepts of loss, risk and decision functions, admissible and optimal decision functions, estimation and testing viewed as decision problems, conjugate families, Bayes and Minimax decision functions with applications to estimation with quadratic loss.

Unit V

Non-parametric tests : Sign test, Wilcoxon signed rank test, Runs test for randomness, Kolmogorov – Smirnov test for goodness of fit, Median test and Wilcoxon-Mann-Whitney U-test. Chi-square test for goodness of fit and test for independence of attributes. Spearman's rank correlation and Kendall's Tau tests for independence.

VI. Practical

- Methods of estimation - Maximum Likelihood, Minimum c^2 and Moments;
- Confidence Interval Estimation;
- MP and UMP tests;
- Large Sample tests;
- Non-parametric tests, Sequential Probability Ratio Test;
- Decision functions.

VII. Suggested Reading

- Box G.E.P. and Tiao G.C. 1992. Bayesian Inference in Statistical Analysis.John Wiley.
- Casela G and Berger R.L. 2001. Statistical Inference. Duxbury Thompson Learning.
- Christensen R. 1990. Log Linear Models. Springer.
- Conover W.J. 1980. Practical Nonparametric Statistics. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. Modern Mathematical Statistics. JohnWiley.
- Gibbons J.D. 1985. Non Parametric Statistical Inference. 2nd Ed. Marcel Dekker.
- Kiefer J.C. 1987. Introduction to Statistical Inference. Springer.
- Lehmann EL. 1986. Testing Statistical Hypotheses. John Wiley.
- Lehmann EL. 1986. Theory of Point Estimation. John Wiley.
- Randles R.H and Wolfe D.S. 1979. Introduction to the Theory of Nonparametric Statistics. John Wiley.
- Rao C.R. 2009. Linear Statistical Inference and Its Applications, 3rdEd. John Wiley.
- Rohatgi V.K. and Saleh A.K. Md. E. 2005. An Introduction to Probability and Statistics. 2nd Ed. John Wiley.
- Rohtagi V.K. 1984. Statistical Inference. John Wiley
- Sidney S and Castellan N.J. Jr. 1988. Non Parametric Statistical Methods for Behavioral Sci ences. McGraw Hill.
- Wald A. 2004. Sequential Analysis. Dover Publ.
- Michael J.Panik. 2012. Statistical Inference. A John Wiley & Sons, INC, publication

I. Course Title : Design of Experiments

II. Course Code : STAT 563

III. Credit Hours : 3(2+1)

IV. Aim of the course

Design of Experiments provides the statistical tools to get maximum information from least amount of resources. This course is meant to expose the students to the basic principles of design of experiments. The students would also be provided with mathematical background of various basic designs involving one-way and two-way elimination of heterogeneity and their characterization properties. This coursewould also prepare the students in deriving the experiencies for analyis of experimental data.

V. Theory

Unit I

Elements of linear estimation, Gauss Mark off Theorem, relationship between BLUEs and linear zero-functions. Aitken's transformation, test of hypothesis, Analysis of Variance, Partitioning of degrees of freedom.

Unit II

Orthogonality, contrasts, mutually orthogonal contrasts, analysis of covariance; Basic principles of design of experiments, uniformity trials, size and shape of plots andblocks, Randomization procedure.

Unit III

Basic designs - completely randomized design, randomized complete block design and Latin square design; Construction of orthogonal Latin squares, mutually orthogonal Latin squares (MOLS), Youden square designs, Graeco Latin squares.

Unit IV

Balanced Incomplete Block (BIB) designs – general properties and analysis without and with recovery of intra block information, construction of BIB designs. Partially balanced incomplete block designs with two associate classes - properties, analysis and construction, Lattice designs, alpha designs, cyclic designs, augmented designs.

Unit V

Factorial experiments, confounding in symmetrical factorial experiments (2nand 3nseries), partial and total confounding, asymmetrical factorials.

Unit VI

Cross-over designs. Missing plot technique; Split plot and Strip plot design; Groups of experiments.Sampling in field experiments.

VI. Practical

- Determination of size and shape of plots and blocks from uniformity trials data;
- Analysis of data generated from completely randomized design, randomized complete block design;
- Latin square design, Youden square design; Analysis of data generated from a BIB design, lattice design, PBIB designs;
- 2^n, 3^n factorial experiments without and with confounding;
- Split and strip plot designs, repeated measurement design;
- Missing plot techniques,
- Analysis of covariance;
- Analysis of Groups of experiments,
- Analysis of clinical trial experiments.

VII. Suggested Reading

- Chakrabarti M.C. 1962. Mathematics of Design and Analysis of Experiments. Asia Publ.House.
- Cochran W.G. and CoX D.R. 1957. Experimental Designs. 2nd Ed. John Wiley.

- Dean A.M. and Voss D. 1999. Design and Analysis of Experiments. Springer.
- Dey A and Mukerjee R. 1999. Fractional Factorial Plans. John Wiley.
- Dey A 1986. Theory of Block Designs. Wiley Eastern. Hall M Jr. 1986. Combinatorial Theory. John Wiley.
- John J.A. and Quenouille M.H. 1977. Experiments: Design and Analysis. Charles & Griffin.
- Kempthorne, O. 1976. Design and Analysis of Experiments. John Wiley. Khuri AI & Cornell JA. 1996. Response Surface Designs and Analysis. 2nd Ed. Marcel Dekker.
- Kshirsagar A.M. 1983. A Course in Linear Models. Marcel Dekker.
- Montgomery D.C. 2013. Design and Analysis of Experiments. John Wiley & Sons
- Raghavarao D. 1971. Construction and Combinatorial Problems in Design of Experiments. John Wiley
- Searle S.R. 2006. Linear Models. John Wiley.
- Street A.P. and Street D.J. 1987. Combinatorics of Experimental Designs. Oxford Science Publ.
- Design Resources Server. Indian Agricultural Statistics Research Institute (ICAR), New Delhi-110 012, India. Hyperlink "http: //www.iasri.res.in/design" www.drs.icar.gov.in.

I. Course Title : Sampling Techniques

II. Course Code : STAT 564

III. Credit Hours : 3(2+1)

IV. Aim of the course

This course is meant to expose the students to the techniques of drawing representative samples from various populations and then preparing them on the mathematical formulations of estimating the population parameters based on the sample data. The students would also be exposed to the real life applications of sampling techniques and estimation of parameters.

V. Theory

Unit I

Sample survey vs complete enumeration, probability sampling, sample space, sampling design, sampling strategy; Determination of sample size; Confidence- interval; Simple random sampling, Estimation of population proportion, Stratified random sampling, Proportional allocation and optimal allocation, Inverse sampling.

Unit II

Ratio, Product and regression methods of estimation, Cluster sampling, Systematic sampling, Multistage sampling with equal probability, Separate and combined ratio estimator, Double sampling, Successive sampling –two occasions. Unbiased ratio type estimators

Unit III

Non-sampling errors – sources and classification, Non-response in surveys, Randomized response techniques, Response errors/ Measurement error – interpenetrating sub-sampling.

Unit IV

PPS Sampling with and without replacement, Cumulative method and Lahiri's method of selection, Horvitz-Thompson estimator, Ordered and unordered estimators, Sampling strategies due to Midzuno-Sen and Rao-Hartley-Cochran. Inclusion probability proportional to size sampling.

VI. Practical

- Determination of sample size and selection of sample;
- Simple random sampling, Inverse sampling, Stratified random sampling, Cluster sampling, system atic sampling;
- Ratio and regression methods of estimation;
- Double sampling, multi-stage sampling, Imputation methods;
- Randomized response techniques;
- Sampling with varying probabilities.

VII. Suggested Reading

- Cassel C.M., Sarndal C.E. and Wretman J.H. 1977. Foundations of Inference in Survey Sam pling. John Wiley.
- Chaudhari A and Stenger H. 2005. Survey Sampling Theory and Methods. 2nd Ed. Chapman & Hall.
- Chaudhari A and Voss J.W.E. 1988. Unified Theory and Strategies of Survey Sampling. North Holland.
- Cochran W.G. 1977. Sampling Techniques. John Wiley.
- Hedayat A.S. and Sinha B.K. 1991. Design and Inference in Finite Population Sampling. John Wiley.
- Kish L. 1965. Survey Sampling. John Wiley.
- Mukhopadhyay, P. 2008.
- Theory and Methods of Survey Sampling, John Wiley & Sons
- Murthy M.N. 1977. Sampling Theory and Methods. 2nd Ed. Statistical Publ. Society, Calcutta.
- Sukhatme P.V., Sukhatme B.V., Sukhatme S and Asok C. 1984. Sampling Theory of Surveys with Applications. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.
- Thompson SK. 2000. Sampling. John Wiley.
- Kochran WG. 2007. Sampling Techniques. A John Wiley & Sons Publication

I. Course Title : Statistical Genetics

II. Course Code : STAT 565

III. Credit Hours : 3(2+1)

IV. Aim of the course

This course is meant to prepare the students in applications of statistics in quantitative genetics and breeding. The students would be exposed to the physical basis of inheritance, detection and estimation of linkage, estimation of genetic parameters and development of selection indices.

V. Theory

Unit I

Physical basis of inheritance. Analysis of segregation, detection and estimation of linkage for qualitative characters. Amount of information about linkage, combined estimation, disturbed segregation.

Unit II

Gene and genotypic frequencies, Random mating and Hardy -Weinberg law, Application and extension of the equilibrium law, Fisher's fundamental theorem of natural selection. Disequilibrium due to linkage for two pairs of genes, sex-linked genes, Theory of path coefficients.

Unit III

Concepts of inbreeding, Regular system of inbreeding. Forces affecting gene frequency - selection, mutation and migration, equilibrium between forces in large populations, Random genetic drift, Effect of finite populationsize.

Unit IV

Polygenic system for quantitative characters, concepts of breeding value and dominance deviation. Genetic variance and its partitioning, Effect of inbreeding on quantitative characters, Multipleallelism in continuous variation, Sex-linked genes, Maternal effects - estimation of their contribution.

Unit V

Correlations between relatives, Heritability, Repeatability and Genetic correlation. Response due to selection, Selection index and its applications in plants and animals' improvement programmes, Correlated response to selection.

Unit VI

Restricted selection index. Variance component approach and linear regression approach for the analysis of GE interactions. Measurement of stability and adaptability for genotypes. Concepts of general and specific combining ability. Diallel and partial diallel crosses - construction and analysis.

VI. Practical

- Test for the single factor segregation ratios, homogeneity of the families with regard to single factor segregation;
- Detection and estimation of linkage parameter by different procedures;
- Estimation of genotypic and gene frequency from a given data.
- Hardy-Weinberg law;
- Estimation of changes in gene frequency due to systematic forces, inbreeding coefficient, genetic components of variation, heritability and repeatability coefficient, genetic correlation coefficient;
- Examination of effect of linkage, epistasis and inbreeding on mean and variance of metric traits;
- Mating designs;
- Construction of selection index including phenotypic index, restricted selection index. Corre lated response to selection.

VII. Suggested Reading

- Agarwal BL and Agarwal SP. 2007. Statistical Analysis of Quantitative Genetics. New Age International Publisher.
- Bailey NTJ. 1961. The Mathematical Theory of Genetic Linkage.Clarendon Press.
- Balding DJ, Bishop M and Cannings C. 2001. Hand Book of Statistical Genetics. John Wiley.
- Crow JF and Kimura M. 1970. An Introduction of Population Genetics Theory. Harper and Row.

- Dahlberg G. 1948. Mathematical Methods for Population Genetics. Inter Science Publ.
- East EM and Jones DF. 1919. Inbreeding and Outbreeding.
- Lippincott JB & Co. Ewens WJ. 1979. Mathematics of Population Genetics. Springer.
- Falconer DS.1985. Introduction to quantitative Genetics.ELBL.
- Fisher RA. 1949. The Theory of Inbreeding. Oliver & Boyd.
- Fisher RA. 1950. Statistical Methods for Research Workers. Oliver& Boyd.
- Fisher RA. 1958. The Genetical Theory of Natural Selection. Dover Publ.
- Kempthorne O. 1957. An Introduction to Genetic Statistics. The Iowa State Univ. Press.
- Lerner IM. 1950. Population Genetics and Animal Improvement.Cambridge Univ. Press.
- Lerner IM. 1954. Genetic Homeostasis. Oliver & Boyd.
- Lerner IM. 1958. The Genetic Theory of Selection. John Wiley.
- Li CC. 1982. Population Genetics. The University of Chicago Press.
- K & Jinks JL. 1977. Introduction to Biometrical Genetics.Chapman & Hall.
- Mather K and Jinks JL. 1982. Biometrical Genetics. Chapman & Hall.
- Mather K. 1949. Biometrical Genetics. Methuen.
- Mather K. 1951. The Measurement of Linkage in Heredity.
- Methuen. N. P. 1990. Statistical Genetics. Wiley Eastern.

I. Course Title : Statistical Quality Control

II. Course Code : STAT 566

III. Credit Hours : 2(2+0)

IV. Aim of the course

This course is meant for exposing the students to the concepts of Statistical Quality Control and their applications in agribusiness and agro- processing industries. This course would enable the students to have an idea about the statistical techniques used in quality control. Students who do not have sufficient background of Statistical Methods.

V. Theory

Unit I

Introduction to Statistical Quality Control; Control Charts for Variables – Mean, Standard deviation and Range charts; Statistical basis; Rational subgroups.

Unit II

Control charts for attributes- 'np', 'p' and 'c' charts.

Unit III

Fundamental concepts of acceptance, sampling plans, single, double and sequential sampling plans for attributes inspection.

Unit IV

Sampling inspection tables for selection of single and double sampling plans.

VI. Suggested Reading

- Cowden D.J. 1957. Statistical Methods in Quality Control. Prentice Hall of India.
- Dodge H.F. and Romig H.G. 1959. Sampling Inspection Tables. John Wiley.
- Duncan A.J. 1986. Quality Control and Industrial Statistics. 5th Ed. Irwin Book Co.
- Grant E.L. and Leavenworth R.S. 1996. Statistical Quality Control. 7th Ed. McGraw Hill.
- Montgomery D.C. 2008. Introduction to Statistical Quality Control. 6th Ed. John Wiley.
- Wetherhil G.B. 1977. Sampling Inspection and Quality Control. Halsted Press.

I. Course Title : Optimization Techniques

II. Course Code : STAT 567

III. Credit Hours : 2(1+1)

IV. Aim of the course

This course is meant for exposing the students to the mathematical details of the techniques optimization techniques. They will be taught numerical methods of optimization, linear programming techniques, nonlinear programming and multiple objective programming. Students will also be exposed to practical applications of these techniques.

V. Theory

Unit I

Classification of optimization problems, Classical optimization techniques: single variable optimization, multivariable optimization techniques with no constraints, multivariable optimization techniques with equality constraints, multivariable optimization techniques with inequality constraints.

Unit II

Linear programming: simplex method, duality, sensitivity analysis, Karmarkar's method, transportation problem.

Unit III

Nonlinear programming Unconstrained optimization techniques: direct search methods such as random search, grid search, Hooke and Jeeves' method, Powel's method. Descent methods such as gradient method, steepest descent method, conjugate gradient method, Newton's method, Marquardt method.

Unit IV

Quadratic programming, integer linear programming, integer nonlinear programming, geometric programming, dynamic programming, stochastic programming, multiobjective optimization, optimal control theory, genetic algorithms, simulated annealing, neural network based optimization,

VI. Practical

- Problems based on classical optimization techniques, optimization techniques with constraints, minimization problems using numerical methods.
- Linear programming (LP) problems through graphical method, simplex method, simplex two-phase method, primal and dual method.

- Sensitivity analysis for LP problem, LP problem using Karmarkar's method.
- Problems based on Quadratic programming, integer programming, dynamic programming, sto chastic programming.
- Problems based on Pontryagin's maximum principle.
- Problems based on multiobjective optimization.

VII. Suggested Reading

- Antunes C.H., Alves, M.J., Climaco J. 2016. Multi objective Linear and Integer Programming (EURO Advanced Tutorials on Operational Research)
- Nocedal, J. and Wright, S.J. 1999. Numerical Optimization. Springer.
- Rao, S.S. 2007. Engineering Optimization: Theory and Practice. New Age International Publish ers.
- Rustagi, J.S. 1994. Optimization Techniques in Statistics. Academic Press.
- Taha, H.A. 2007. Operations Research: Introduction with CD. Pearson Education.
- Xu, H, Teo, K.L. Zhang Y. 2016. Optimization and Control Techniques and Applications (Springer Proceedings in Mathematics & Statistics)
- Zeleny, M. 1974. Linear Multi objective Programming. Springer.

I. Course Title : Multivariate Analysis

II. Course Code : STAT 571

III. Credit Hours : 3(2+1)

IV. Aim of the course

This course lays the foundation of Multivariate data analysis. Most of the data sets in agricultural sciences are multivariate in nature. The exposure provided to multivariate data structure, multinomial and multivariate normal distribution, estimation and testing of parameters, various data reduction methods would help the students in having a better understanding of agricultural research data, its presentation and analysis.

V. Theory

Unit I

Concept of random vector, its expectation and Variance-Covariance matrix. Marginal and joint distributions. Conditional distributions and Independence of random vectors. Multinomial distribution. Multivariate Normal distribution, marginal and conditional distributions. Sample mean vector and its distribution. Maximumlikelihood estimates of mean vector and dispersion about mean vector.

Unit II

Wishart distribution and its simple properties. Hotelling's T^2 and Mahalanobis D^2 statistics. Null distribution of Hotelling's T^2. Rao's U statistics and its distribution. Wilks' $>_2$criterion and its properties. Concepts of discriminant analysis, computation of linear discriminant function, classification between k multivariate normal populations based on LDF and Mahalanobis D^2.

Unit III

Principal Component Analysis, factor analysis. Canonical variables and canonical correlations. Cluster analysis: similarities and dissimilarities of qualitative and quantitative characteristics, Hierarchical clustering. Single, Complete and Average linkage methods. K-means cluster analysis.

Unit IV

Path analysis and computation of path coefficients, introduction to multidimensional scaling, some theoretical results, similarities, metric and non-metric scaling methods.

VI. Practical

- Maximum likelihood estimates of mean-vector and dispersion matrix;
- Testing of hypothesis on mean vectors of multivariate normal populations;
- Cluster analysis, Discriminant function, Canonical correlation, Principal component analysis, Fac tor analysis;
- Multivariate analysis of variance and covariance, multidimensional scaling.

VII Suggested Reading

- Abdelmonem A, Virginia AC and Susanne M. 2004. Computer Aided Multivariate Analysis. Chapman & Hall/CRC.
- Anderson TW. 1984. An Introduction to Multivariate Statistical Analysis. 2nd Ed. John Wiley.
- Arnold SF. 1981. The Theory of Linear Models and Multivariate Analysis. John Wiley.
- Giri NC. 1977. Multivariate Statistical Inference. Academic Press.
- Johnson RA and Wichern DW. 1988. Applied Multivariate Statistical Analysis. Prentice Hall.
- Kshirsagar AM. 1972. Multivariate Analysis. Marcel Dekker.
- Muirhead RJ. 1982. Aspects of Multivariate Statistical Theory. John Wiley. Muirhead, RJ. (2005) Aspects of Multivariate Statistical Theory. 2nd Ed. John Wiley.
- Rao CR. 1973. Linear Statistical Inference and its Applications. 2nd Ed. John Wiley.
- Rencher AC. 2012. Methods of Multivariate Analysis. 3rd Ed. John Wiley.
- Srivastava MS and Khatri CG. 1979. An Introduction to Multivariate Statistics. North Holland.

I. Course Title : Regression Analysis

II. Course Code : STAT 572

III. Credit Hours : 2(1+1)

IV. Aim of the course

This course is meant to prepare the students in linear and non-linear regression methods useful for statistical data analysis. They would also be provided a mathematical foundation behind these techniques and their applications in agricultural data.

V. Theory

Unit I

Simple and Multiple linear regressions: Least squares fit, Properties and examples. Polynomial regression: Use of orthogonal polynomials.

Unit II

Assumptions of regression; diagnostics and transformations; residual analysis Studentized residuals, applications of residuals in detecting outliers, identification of influential observations. Lack of fit, Pure error. Test of normality, test of linearity,Testing homoscedasticity and normality of errors, Durbin-Watson test. Test of goodness of fit for the model evaluation and validation.Concept of multi-collinearity

Unit III

Weighted least squares method: Properties, and examples. Box-Cox family of transformations. Use of dummy variables, Over fitting and under fitting of model, Selection of variables: Forward selection, Backward elimination. Stepwise and Stagewise regressions.

Unit IV

Introduction to non-linear models, nonlinear estimation: Least squares for nonlinear models.

VI. Practical

- Multiple regression fitting with three and four independent variables;
- Estimation of residuals, their applications in outlier detection, distribution of residuals;
- Test of homoscedasticity, and normality, Box-Cox transformation;
- Restricted estimation of parameters in the model, hypothesis testing, Step wise regression analy sis;
- Least median of squares norm, Orthogonal polynomialfitting.

VII. Suggested Reading

- Barnett V and Lewis T. 1984. Outliers in Statistical Data. John Wiley.
- Belsley DA, Kuh E and Welsch RE. 2004. Regression Diagnostics-Identifying Influential Data and Sources of Collinearity. John Wiley.
- Chatterjee S and Hadi AS. 2013. Regression Analysis by Example. A John Wiley & sons Publication.
- Draper NR and Smith H. 1998. Applied Regression Analysis. 3rd Ed. John Wiley.
- McCullagh P and Nelder JA. 1999. Generalized Linear Models. 2nd Ed.Chapman & Hall.
- Montgomery DC, Peck EA and Vining GG. 2003. Introduction to Linear Regression Analysis. 3rd Ed. John Wiley.
- Rao CR. 1973. Linear Statistical Inference and its Applications. 2nd Ed. John Wiley.

I. Course Title : Statistical Computing

II. Course Code : STAT 573

III. Credit Hours : 2(1+1)

IV. Aim of the course

This course is meant for exposing the students in the concepts of computational techniques. Various statistical packages would be used for teaching the concepts of computational techniques.

V. Theory

Unit I

Introduction to statistical packages and computing: data types and structures, Use of Software packages like, SAS, SPSS or "R: The R Project for Statistical Computing". Data analysis principles and practice, Summarization and tabulation of data, Exploratory data analysis; Graphical representation of data.Statistical Distributions: Fitting and testing the goodness of fit of discrete and continuous probability distributions;

Unit II

ANOVA, regression and categorical data methods; model formulation, fitting, diagnostics and validation; Matrix computations in linear models. Analysis of discrete data. Multiple comparisons, Contrast analysis.

Unit III

Numerical linear algebra, numerical optimization, graphical techniques, numerical approximations, Time Series Analysis.

Unit IV

Analysis of mixed models; Estimation of variance components, Analysis of Covariance, Fitting of non-linear model, Discriminant function; Principal component analysis. techniques in the analysis of survival data and longitudinal studies, Approaches to handling missing data, and meta-analysis

VI. Practical

- Data management, Graphical representation of data, Descriptive statistics;
- General linear models ~ fitting and analysis of residuals, outlier detection;
- 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, test for large samples - Chi-squares test, F test, One way analysis of variance, contrast and its testing, pairwise comparisons;
- Mixed effect models, estimation of variance components;
- Categorical data analysis, dissimilarity measures, similarity measures;
- Analysis of discrete data, analysis of binary data;
- Numerical algorithms;
- Spatial modeling, cohort studies;
- Clinical trials, analysis of survival data;
- Handling missing data.Analysis of time series data - fitting of ARIMA models.

VII. Suggested Reading

- Agresti A. 2013. Categorical Data Analysis. 3rd Ed. John Wiley.
- Everitt BS and Dunn G. 1991. Advanced Multivariate Data Analysis. 2nd Ed. Arnold.
- Geisser S. 1993. Predictive Inference: An Introduction. Chapman & Hall.
- Gelman A & Hill J. 2006. Data Analysis Using Regression and Multilevel/Hierarchical Models. Cambridge Univ. Press.
- Gentle JE, Härdle W and Mori Y. 2012. Handbook of Computational Statistics - Concepts and Methods. 2nd Ed. Springer.

- Han J and Kamber M. 2000. Data Mining: Concepts and Techniques. Morgan.
- Hastie T, Tibshirani R and Friedman R. 2001. The Elements of Statistical Learning: Data Mining, Inference and Prediction. Springer.
- Kennedy WJ & Gentle JE. 1980. Statistical Computing. Marcel Dekker.
- Miller RG Jr. 1986. Beyond ANOVA, Basics of Applied Statistics. John Wiley.
- Rajaraman V. 1993. Computer Oriented Numerical Methods. Prentice-Hall.
- Ross S. 2000. Introduction to Probability Models. Academic Press.
- Ryan BF and Joiner BL. 1994. MINITAB Handbook. 3rd Ed. DuXbury Press.
- Simonoff JS. 1996. Smoothing Methods in Statistics. Springer.
- Singh, AK. 2016. Practical R-Book by Examples for Agricultural Statistics. Deptt. Of Ag. Statistics, IGKV. Raipur
- Snell EJ. 1987. Applied Statistics: A Handbook of BMDP Analyses. Chapman & Hall.
- Thisted RA. 1988. Elements of Statistical Computing. Chapman & Hall.
- Venables WN and Ripley BD. 1999. Modern Applied Statistics With S-Plus. 3rd Ed. Springer.
- http: //www.r-project.org/
- http: //www.stat.sc.edu/~grego/courses/stat706/.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Time Series Analysis

II. Course Code : STAT 574

III. Credit Hours : 2(1+1)

IV. Aim of the course

This course is meant to teach the students the concepts involved in time series data. They would also be exposed to components of time series, stationary models and forecasting/ projecting the future scenarios based on time series data. It would also help them in understanding the concepts involved in time series data presentation, analysis and interpretation.

V. Theory

Unit I

Components of a time-series. Autocorrelation and Partial autocorrelation functions, Correlogram and periodogram analysis.

Unit II

Linear stationary models: Autoregressive, moving average and Mixed processes. Linear non-stationary models: Autoregressive integrated moving average processes.

Unit III

Forecasting: Minimum mean square forecasts and their properties, Calculating and updating forecasts.

Unit IV

Model identification: Objectives, Techniques, and Initial estimates. Model estimation: Likelihood function, Sum of squares function, Least squares estimates. Seasonal models. Intervention analysis models and Outlier detection.

VI. Practical

Time series analysis, autocorrelations, correlogram and periodogram; Linear stationary model; Linear non-stationary model; Model identification and model estimation; Intervention analysis and outlier detection.

VII. Suggested Reading

- Box GEP, Jenkins GM and Reinsel GC. 2007. Time Series Analysis: Forecasting and Control. 3rd Ed. Pearson Edu.
- Brockwell PJ and Davis RA. 2002. Introduction to Time Series and Forecasting. 2nd Ed. Springer.
- Chatterjee S, Hadi A and Price B.1999. Regression Analysis by Examples.John Wiley.
- Draper NR and Smith H. 1998. Applied Regression Analysis. 3rd Ed. John Wiley.
- Jenkins, GM, Reinsel, GC, Greta M. L,George E.P.B. 2015. Time Series Analysis: Forecasting and Control, Wiley Series in Probability and Statistics
- Johnston J. 1984. Econometric Methods. McGraw Hill.
- Judge GG, Hill RC, Griffiths WE, Lutkepohl H and Lee TC. 1988. Introduction to the Theory and Practice of Econometrics. 2nd Ed. John Wiley.
- Montgomery DC and Johnson LA. 1976. Forecasting and Time Series Analysis. McGraw Hill.
- Montgomery DC, Jennings CA and Kulahci M. 2015. Introduction to Time Series Analysis and Forecasting, Wiley Series in Probability and Statistics
- Shumway RH and Stoffer DS. 2006. Time Series Analysis and its Applications: With R Ex amples. 2nd Ed. Springer.

I. Course Title : Demography

II. Course Code : STAT 575

III. Credit Hours : 2(2+0)

IV. Aim of the course

This course is meant for training the students in measures of demographic indices, estimation procedures of demographic parameters. Students would also be exposed to population projection techniques and principle involved inbioassays.

V. Theory

Unit I

Introduction to vital statistics, crude and standard mortality and morbidity rates, Estimation of mortality, Measures of fertility and mortality, period and cohort measures.

Unit II

Life tables and their applications, methods of construction of abridged life tables, Increment-Decrement Life Tables.

Unit III

Stationary and stable populations, Migration and immigration. Application of stable population theory to estimate vital rates, migration and its estimation. Demographic relations in Nonstable populations. Measurement of population growth, Lotka's model (deterministic) and intrinsic rate of growth, Measures of mortality and morbidityPeriod.

Unit IV

Principle of biological assays, parallel line and slope ratio assays, choice of doses and efficiency in assays quantal responses, probit and logit transformations, epidemiological models.

VI. Suggested Reading

- Cox DR. 1957. Demography. Cambridge Univ. Press.
- Charles Griffin. Fleiss JL. 1981. Statistical Methods for Rates and Proportions. John Wiley.
- Finney DJ. 1981. Statistical Methods in Biological Assays.
- Grow A, Bavel JV. 2016. Agent-Based Modelling in Population Studies: Concepts, Methods, and Applications (The Springer Series on Demographic Methods and Population Analysis)
- Lawless JF. 1982. Statistical Models and Methods for Lifetime Data. John Wiley.
- MacMahon B and Pugh TF. 1970. Epidemiology- Principles and Methods.Little Brown, Boston.
- Mann NR, Schafer RE and Singpurwalla ND. 1974. Methods for Statistical Analysis of Reliabil ity and Life Data. John Wiley.
- Newell C. 1988. Methods and Models in Demography. Guilford Publ.
- Preston S, Heuveline P and Guillot M. 2001. Demography: Measuring and Modeling Population Processes. Blackwell Publ.
- Rowland DT. 2004. Demographic Methods and Concepts. OXford Press.
- Siegel JS and Swanson DA. 2004. The Methods and Material ofDemography. 2nd Ed. Elsevier.
- Woolson FR. 1987. Statistical Methods for the Analysis of Biomedical Data. JohnWiley.
- Yakovlev AY, Klebanov L and Gaile D. 2013. Statistical Methods for Microarray Data Analysis: Methods and Protocols (Methods in Molecular Biology)

I. Course Title : Statistical Methods for Life Sciences

II. Course Code : STAT 576

III. Credit Hours : 2(2+0)

IV. Aim of the course

This course focuses on statistical methods for discrete data collected in public health, clinical and biological studies including survival analysis. This would enable the students to understand the principles of different statistical techniques useful in public health and clinical studies conducted.

V. Theory

Unit I

Proportions and counts, contingency tables, logistic regression models, Poisson regression and log-linear models, models for polytomous data and generalized linear models.

Unit II

Computing techniques, numerical methods, simulation and general implementation of biostatistical analysis techniques with emphasis on data applications. Analysis of survival time data using parametric and non- parametric models, hypothesis testing, and methods for analyzing censored (partially observed) data with covariates. Topics include marginal estimation of a survival function, estimation of a generalized multivariate linear regression model (allowing missing covariates and/or outcomes).

Unit III

Proportional Hazard model: Methods of estimation, estimation of survival functions, time-dependent covariates, estimation of a multiplicative intensity model (such as Cox proportional hazards model) and estimation of causal parameters assuming marginal structural models.

Unit IV

General theory for developing locally efficient estimators of the parameters of interest in censored data models. Rank tests with censored data. Computing techniques, numerical methods, simulation and general implementation of bio- statistical analysis techniques with emphasis on data applications.

Unit V

Newton, scoring, and EM algorithms for maximization; smoothing methods; boot strapping; trees and neural networks; clustering; isotonic regression; Markov chain Monte Carlo methods.

VI. Suggested Reading

- Biswas S. 2007. Applied Stochastic Processes. A Biostatistical and Population Oriented Ap proach. Wiley Eastern Ltd.
- Collett D. 2003. Modeling Survival Data in Medical Research. Chapman & Hall.
- CoX D.R. and Oakes D. 1984. Analysis of Survival Data. Chapman & Hall.
- Hosmer DW Jr. and Lemeshow S. 1999. Applied Survival Analysis: Regression Modeling or Time to Event. John Wiley.
- Klein J.P. and Moeschberger M.L. 2003. Survival Analysis: Techniques for Censored and Trun cated Data. Springer.
- Kleinbaum D.G. and Klein M 2005. Survival Analysis. A Self Learning Text. Springer.
- Kleinbaum D.G. and Klein M. 2005. Logistic Regression. 2nd Ed. Springer.
- Lee ET. 1992. Statistical Methods for Survival Data Analysis.
- John Wiley and Miller RG. 1981. Survival Analysis. John Wiley.
- Therneau T.M. and Grambsch P.M. 2000. Modeling Survival Data: Extending the Cox Model.Springer.

I. Course Title : Statistical Ecology

II. Course Code : STAT 577

III. Credit Hours : 2(2+0)

IV. Aim of the courseThis course is meant for

Exposing the students to the importance and use of statistical methods in collections of ecological data, species-abundance relations, community classification and community interpretation.

V. Theory

Unit I

Ecological data, Ecological sampling; Spatial pattern analysis: Distribution methods, Quadrant-variance methods, Distancemethods.

Unit II

Species-abundance relations: Distribution models, Diversity indices; Species affinity: Niche-overlap indices, interspecific association, interspecificcovariation.

Unit III

Community classification: Resemblance functions, Association analysis, Cluster analysis; Community Ordination: Polar Ordination, Principal Component Analysis, Correspondence analysis, Nonlinear ordination.

Unit IV

Community interpretation: Classification Interpretation and Ordination Interpretation.

VI. Suggested Reading

- Gotelli N.J. and Ellison A.M. 2004. A Primer of Ecological Statistics
- Pielou E.C. 1970. An introduction to Mathematical Ecology. John Wiley.
- Reynolds J.F. and Ludwig J.A. 1988. Statistical Ecology: A Primer on Methods and Computing. JohnWiley.
- Young L.J., Young J.H. and Young J. 1998. Statistical Ecology: A Population Perspective. Kluwer.

BIOCHEMISTRY

M.Sc (Agri) in Biochemistry

Course Code	Course Title	Credit Hours
BIOCHEM 501	Basic Biochemistry	4(3+1)
BIOCHEM 502	Intermediary Metabolism	3(3+0)
BIOCHEM 503	Enzymology	3(2+1)
BIOCHEM 504	Molecular Biology	3(2+1)
BIOCHEM 505	Techniques In Biochemistry	4(2+2)
BIOCHEM 506	Immuno Chemistry	3(2+1)
BIOCHEM 507	Plant Biochemistry	3(2+1)
BIOCHEM 509	Nutritional Biochemistry	3(2+1)

Course Contents
M.Sc (Agri) in Biochemistry

I. Course Title : Basic Biochemistry

II. Course Code : BIOCHEM 501

III. Credit Hours : 4(3+1)

IV. Why this course?

To impart the fundamental knowledge on structure and function of cellular components involved in biological processes and an elementary introduction to the study of molecular biology.

V. Aim of the course

The course is designed to provide elementary knowledge/overview of structure and function of proteins, carbohydrates, lipids, nucleic acids and other biomolecules and their metabolism.

No.	Blocks	Units
1.	Introduction to Biochemistry	1. Scope and importance of biochemistry 2. Foundation of life 3. Water 4. Physical techniques for structure determination
2.	Structure and function of Biomolecules	1. Biomolecules 2. Immunoglobulins and PR proteins 3. Plant secondary metabolites
3.	Metabolism – the basics	1. Molecules aiding metabolism 2. Thermodynamics –principles and energetic of life
4.	Catabolism and its regulation	1. Catabolism of energy molecules 2. ATP formation
5.	Fundamentals of Molecular biology and genetic engineering	1. Molecular biology processes 2. Recombinant DNA technology

VI. Theory

Block 1: Introduction to Biochemistry

Unit 1: Scope and importance of biochemistry (1 Lecture)

Biochemistry as modern science and its various divisions, Scope and importance of biochemistry in agriculture and allied sciences.

Unit 2: Foundation of life (2 Lectures)

Fundamental principles governing life, supramolecular structures, significance of weak non covalent interactions in biology

Unit 3: Water (3 Lectures)

Structure of water, ionization of water, acid base concept, pH and buffers, significance of structure-function relationship.

Unit 4: Physical techniques for structure determination (2 Lectures)

General introduction to physical techniques for determination of structure of biopolymers.

Block 2: Structure And Function of Biomolecules

Unit 1: Biomolecules (10 Lectures)

Structure, classification, properties and function of carbohydrates, amino acids, proteins, lipids and nucleic acids.

Unit 2: Immunoglobulins and PR proteins (2 Lectures)

Structure, formation and different forms of immunoglobulins, PR proteins and their classification.

Unit 3: Plant secondary metabolites (3 Lectures)

Structure, classification and function of plant secondary metabolites.

Block 3: Metabolism – The Basics

Unit 1: Molecules aiding metabolism (2 Lectures)

Structure and biological functions of vitamins and coenzymes, enzymes: classification and mechanism of action; regulation, factors affecting enzyme action. Hormones: animal and plants.

Unit 2: Thermodynamics –principles and energetic of life (2 Lectures)

Fundamentals of thermodynamic principles applicable to biological processes, Bioenergetics.

Block 4: Catabolism and its Regulation

Unit 1: Catabolism of energy molecules (5 Lectures)

Important and basic degradative metabolic pathways of carbohydrates, lipids and proteins and their regulation.

Unit 2: ATP formation (3 Lectures)

Formation of ATP, substrate level phosphorylation, electron transport chain and oxidative phosphorylation, chemiosmotic theory and proton motive force.

Block 5: Fundamentals of Molecular Biology and Genetic Engineering

Unit 1: Molecular biology processes (4 Lectures)

Overview of replication, transcription and translation.

Unit 2: Recombinant DNA technology (3 Lectures)

Restriction enzymes, DNA cloning, applications of cloning, transgenics.

VII. Practicals

- Preparation of standard and buffer solutions
- Detection of carbohydrates, amino acids and proteins
- Extraction and estimation of sugars

- Extraction and estimation of amino acids
- Extraction and estimation of proteins
- Estimation of acid value of fat/oil
- Estimation of peroxide value of fat/oil
- Estimation of saponification value in fats and oils
- Fatty acid composition in fat/oil by GC
- Estimation of DNA and RNA by spectroscopic methods
- Estimation of Ascorbic acid
- Separation of biomolecules by TLC and Paper chromatography
- Estimation of alpha amylase activity
- Qualitative tests for secondary plant metabolites.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz

IX. Learning outcome

With this course, the students are expected to be able to understand the actual chemical concepts and fundamental processes of biology at molecular level.

X. Suggested Reading

- Nelson DL and Cox MM. 2017. Lehninger Principles of Biochemistry. 7th edition. W. H. Freeman & Co Ltd
- Satyanarayana U and Chakrapani U. 2017. Biochemistry. 5th edition, Elsevier
- Moran LA, Horton HR, Scrimgeour KG and Perry MD. 2012. Principles of Biochemistry. 5th edition Pearson.
- Voet D and Voet JG. 2011. Biochemistry. 4th edition John Wiley.
- Pratt CW and Cornely K. 2014. Essential Biochemistry. 3rd Edition. Wiley
- Moorthy K. 2007. Fundamentals of Biochemical Calculations. 2nd edition. CRC Press
- Conn EE, Stumpf PK, Bruening G and Doi RH. 2006. Outlines of Biochemistry. 5th edition. Wiley.

I. Course Title : Intermediary Metabolism

II. Course Code : BIOCHEM 502

III. Credit Hours : 3(3+0)

IV. Why this course?

To understand the interconversion of chemical compounds in the living system, the pathways taken by individual molecules, their interrelationships and the mechanisms that regulate the flow of metabolites through the pathways.

V. Aim of the course

The course is designed to give an insight into the different metabolic pathways, their interrelationship, regulation, metabolic disorders in human and pathway engineering in plants.

No.	Blocks	Units
1.	Introduction to metabolism	1. Overview of metabolism 2. Metabolic pathways
2.	Metabolism of energy nutrients	1. Carbohydrate metabolism 2. Lipid metabolism 3. Protein metabolism 4. Energy transduction and oxidative phosphorylation
3.	Sulphur and nucleotide metabolism	1. Sulphur metabolism 2. Nucleotide metabolism
4.	Metabolic regulation and defects in metabolism	1. Regulation of metabolic pathways 2. Defects in metabolism

VI. Theory

Block 1: Introduction To Metabolism

Unit 1: Overview of metabolism (4 Lectures)

The living cell - a unique chemical system, biochemical reaction types, bioenergetics, bioavailability of nutrients, transport mechanism, signal transduction.

Unit 2: Metabolic pathways (5 Lectures)

Catabolism and anabolism, compartments of metabolic pathways, experimental approaches to study metabolism, metabolic profiles of major organs.

Block 2: Metabolism of Energy Nutrients

Unit 1: Carbohydrate metabolism (5 Lectures)

Major catabolic and anabolic pathways of carbohydrate metabolism, the glyoxylate pathway.

Unit 2: Lipid metabolism (5 Lectures)

Fatty acid oxidation, ketone bodies, fatty acid biosynthesis, synthesis of triacylglycerols, cholesterol, eicosanoids.

Unit 3: Protein metabolism (3 Lectures)

General reactions of amino acid metabolism, degradative and biosynthetic pathways of amino acids, urea cycle, amino acids as metabolic precursors.

Unit 4: Energy transduction and oxidative phosphorylation (4 Lectures)

Mechanisms of energy transduction, electron transport system, phosphorylation, control of ATP production.

Block 3.sulphur and Nucleotide Metabolism

Unit 1: Sulphur metabolism (5 Lectures)

Sulphate reduction and incorporation of sulphur in to amino acids.

Unit 2: Nucleotide metabolism (3 Lectures)

Synthesis and degradation of purine and pyrimidine nucleotides.

Block 4: Metabolic Regulation and Defects in Metabolism

Unit 1: Regulation of metabolic pathways (4 Lectures)

Regulation of carbohudrate, lipid, protein, nucleotide metabolism and oxidative phosphorylation.

Unit 2: Defects in metabolism (4 Lectures)

Disorders of carbohydrates, lipids, amino acids and nucleic acid metabolism, and inborn errors of metabolism. Metabolic pathway engineering.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

With this course, the students are expected to learn the set of life-sustaining chemical processes that enables organisms transform the chemical energy stored in molecules into useful form and the process by which organisms respond to stimuli and metabolic disorders.

IX. Suggested Reading

- Nelson, D. L. and Cox, M. M. 2017. Lehninger Principles of Biochemistry. 7th edition. W. H. Freeman & Co Ltd
- Satyanarayana, U. and Chakrapani, U. 2017. Biochemistry. 5th edition, Elsevier
- Campbell M. K. and Farrell S.O. 2009. Biochemistry. 6thedition Thomson Higher Education.
- Moran L. A., Horton H. R., Scrimgeour K. G. and Perry, M. D. 2012. Principles of Biochem istry. 5th edition Pearson,
- Voet, D. and Voet J. G. 2011. Biochemistry. 4thedition . John Wiley.
- Pratt, C. W. and Cornely, K. 2014. Essential Biochemistry. 3rd Edition. Wiley
- Moorthy, K. 2007. Fundamentals of Biochemical Calculations. 2nd edition. CRC Press

I. Course Title : Enzymology

II. Course Code : BIOCHEM 503

III. Credit Hours : 3(2+1)

IV. Why this course?

Being highly specific and incredibly efficient biological catalysts, enzymes are responsible for bringing about almost all of the chemical reactions in living organisms. Otherwise these reactions will take place at a rate far too slow for the pace of metabolism. The course will help students in understanding the physical, chemical and kinetic properties of enzymes.

V. Aim of the course

To impart knowledge about the catalytic role of enzymes, their structure, physico- chemical, kinetic and regulatory properties and mechanism of action.

No.	Blocks	Units
1.	Introduction to enzymes	1. Structure and function of enzyme
		2. Extraction and purification of enzymes
2.	Enzyme structure and function	1. Chemical nature of enzyme
		2. Cofactors and coenzymes
		3. Nature of active site
3.	Enzyme kinetics	1. Single substrate kinetics
		2. Enzyme inhibition
		3. Kinetics of allosteric enzymes
		4. Regulation of enzyme activity
4.	Application of enzymology	1. Industrial application of enzymes
		2. Biotechnological application of enzymes

VI. Theory

Block 1: Introduction To Enzymes

Unit 1: Structure and function of enzyme (2 Lectures)

Historic perspective, general properties of enzymes, enzyme compartmentalization in cell organelles, nomenclature and classification of enzymes, ribozymes, isozymes, abzymes.

Unit 2: Extraction and purification of enzymes (2 Lectures)

Extraction of soluble and membrane-bound enzymes, purification of enzymes, measurement of enzyme activity.

Block 2: Enzyme Structure and Function

Unit 1: Chemical nature of enzyme (3 Lectures)

Enzyme specificity, monomeric and oligomeric enzymes, catalytic mechanism, mechanism of enzyme action, pseudoenzymes, enzyme promiscuity.

Unit 2: Cofactors and coenzymes (2 Lectures)

Chemical nature and involvement of cofactors and coenzymes in enzyme catalyzed reactions, metal activated enzymes and metalloenzymes, mechanism of enzyme catalyzed reactions without cofactors.

Unit 3: Nature of active site (2 Lectures)

Active site, identification of binding sites and catalytic sites.

Block 3. Enzyme Kinetics

Unit 1: Single substrate kinetics (4 Lectures)

Relationship between initial velocity and substrate concentration, Michaelis-Menten equation, Lineweaver-Burk and Eadie-Hofstee plots, analysis of kinetic data, numerical exercises.

Unit 2: Enzyme inhibition (2 Lectures)

Reversible and irreversible enzyme inhibition, uses of enzyme inhibition.

Unit 3: Kinetics of allosteric enzymes (3 Lectures)

Nature of allosteric enzymes, sigmoidal kinetics, MWC model and allosteric regulation, KNF model and allosteric regulation.

Unit 4: Regulation of enzyme activity (3 Lectures)

Feedback regulation, regulatory enzymes, control of enzymatic activity, symmetry and sequential model, reversible covalent modification of enzymes.

Block 4: Application of Enzymology

Unit 1: Industrial application of enzymes (3 Lectures)

Industrial application of enzyme catalysis in sectors like food processing, detergents,

Unit 2 : Biotechnological application of enzymes (2 Lectures)

Large scale production and purification of enzymes, immobilization of enzymes.

VII. Practicals

- Soluble protein estimation
- Enzyme assay by taking any model enzyme
- Isolation and purification of any model enzyme
- Study of the effect of enzyme and substrate concentrations on enzyme activity
- Determination of KM and Vmax
- Determination of pH and temperature optima
- Effect of inhibitors on enzyme activity
- Determination of pH and temperature stability of enzyme
- Electrophoretic analysis of isozymes.

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)

– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the chemical principles of enzyme catalysis, action of enzymes as biocatalysts and factors that influence enzyme activity and understand the kinetics of enzymatic reactions. Students will have experience with purification, handlingand characterization of proteins and also get enzymes and their future potential.

X. Suggested Reading

- Palmer T and Bonner PL. 2007. Enzymes: Biochemistry, Biotechnology, Clinical Chemistry. 2nd edition. Woodhead Publishing
- Okotore RO. 2015. Essentials of Enzymology. XLIBRIS
- Herald J. 2016. Essentials of Enzymology. Syrawood Publishing House
- Suzuki, H. 2015. How Enzymes Work: From Structure to Function. Jenny Stanford Publishing.
- Bugg TDH. 2012. Introduction to Enzyme and Coenzyme Chemistry, 3rd Edition. WILEY
- Guo Y. 2014. Enzyme Engineering. Science Press
- Bisswanger H. 2011. Practical Enzymology. Wiley-Blackwell

I. Course Title : Molecular Biology

II. Course Code : BIOCHEM 504

III. Credit Hours : 3(2+1)

IV. Why this course?

Molecular biology is the study of biology at a molecular level. The concepts and techniques of molecular biology are the foundation for the studies of all aspects of biology in modern time. This course is designed to provide an intensive exposure to the theoretical concepts and experimental techniques of molecular biology and the interrelationship of DNA, RNA and protein synthesis and their regulation.

V. Aim of the course

To provide knowledge of life processes at the molecular and cellular levels, including the storage, transfer and regulation of genetic information and specialist theoretical knowledge and practical experience of gene manipulation and the analysis of nucleic acids and proteins.

No.	Blocks	Units
1.	Introduction to nucleic acids	1. History
		2. Properties of nucleic acid
		3. Genes and genome
2.	Synthesis of nucleic acids	1. DNA replication
		2. Transcription
3.	Protein synthesis	1. Translation machinery
		2. Mechanism of protein synthesis
		3. Post-translational events

4.	Gene manipulation	1.	DNA sequencing
		2.	Recombinant DNA technology
		3.	Techniques in molecular biology

VI. Theory

Block 1: Introduction to Nucleic Acids

Unit 1: History (1 Lecture)

Historical development of molecular biology, nucleic acids as genetic material.

Unit 2: Properties of nucleic acid (2 Lectures)

Nucleic acid structure, chemical and physical properties of nucleic acids, spectroscopic and thermal properties of nucleic acids, DNA supercoiling.

Unit 3: Genes and genome (3 Lectures)

Concept of genes and genome, genome complexity, genome organization in prokaryotes and eukaryotes, chromatin structure and function, repetitive and non- repetitive DNA, satellite DNA central dogma, genome editing.

Block 2: Synthesis of Nucleic Acid

Unit 1: DNA replication (3 Lectures)

Modes of replication, DNA polymerases, topoisomerases, DNA ligase, model of replisome, semi conservative replication in prokaryotes and eukaryotes, inhibitors of replication, DNA damage and repair.

Unit 2: Transcription (3 Lectures)

Basic principles of transcription, transcription initiation, elongation and termination, RNA processing, RNA interference, siRNAs, miRNAs and other ncRNAs, DNA/ RNA editing. regulation of transcription, reverse transcription.

Block 3. Protein Synthesis

Unit 1: Translation machinery (2 Lectures)

Ribosomes structure and function, organization of ribosomal proteins and RNA genes, genetic code, aminoacyl tRNA synthases.

Unit 2: Mechanism of Protein synthesis (2 Lectures)

Initiation, chain elongation and termination of translation, energetics, inhibitors of translation.

Unit 3: Post-translational events (2 Lectures)

Post translational modifications of nascent polypeptide, protein targeting and turnover, regulation of gene expression in prokaryotes and eukaryotes, nucleases and restriction enzymes.

Block 4: Gene Manipulation

Unit 1: DNA sequencing (3 Lectures)

Importance, Sanger method,High-Throughput Sequencing (HTS) techniques, applications of DNA sequencing.

Unit 2: Recombinant DNA technology (4 Lectures)

Vectors, isolation of genes, recombinants vector, selection of recombinants, characterization and expression of cloned DNA, transformation, transgenesis, mutation, molecular mechanism of mutation, site directed mutagenesis, in vitro mutagenesis.

Unit 3: Techniques in molecular biology (3 Lectures)

Polymerase chain reaction (PCR), expression cloning, gel electrophoresis, molecular markers, macromolecule blotting and probing, arrays (DNA array and protein array) – principles and application.

VII. Practicals

- Isolation and purification of DNA and RNA
- To check the purity of isolated DNA and RNA
- Restriction fragmentation of genomic DNA
- Separation of oligos by agarose gel electrophoresis
- Southern blotting experiments
- Northern blotting experiments
- Cloning of DNA fragment in vector
- Selection of recombinant
- SSR analysis of DNA
- cDNA synthesis using RT- PCR
- Basic tools in bioinformatics analysis

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

After completion, the student should be able to explain central cell biological processes and how they are regulated and quality assured and understands how molecular cell biology forms the foundation of biotechnology.

X. Suggested Reading

- Snape A, Papachristodoulou D, Elliott, W. H. and Elliott, C. 2014. Biochemistry and Molecular Biology. Oxford University Press.
- Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. 2018. Lewin's GENES XII. Jones & Bartlett Learning.
- Lodish, H.,Berk, A., Kaiser, C. A., Krieger, M. And Bretscher, A. 2016. Molecular Cell Biology.W H Freeman & Co.
- Hoffmann, A. And Clokie, S. 2018. Wilson and Walker's Principles and Techniques of Biochem istry and Molecular Biology. Cambridge University Press.
- Primrose SB, Twyman RM and Old RW.2002. Principles of Gene Manipulation: 6th Ed. Wiley

- Karp, G. 2013. Cell and Molecular Biology. Wiley.
- Neidle, S. 2008. Principles of Nucleic Acid Structure. Elsevier Inc.
- Watson J, Baker TA, Bell SP, Gann A, Levine M and Losick, R. 2014. Molecular biology of the gene 7th edition, Pearson.

I. Course Title : Techniques in Biochemistry

II. Course Code : BIOCHEM 505

III. Credit Hours : 4(2+2)

IV. Why this course?

Biochemical studies rely on the availability of appropriate analytical techniques and their applications. This course will examine modern methods and technologies that are used in biochemical analysis with emphasis on instrumentation, underlying principles, aims, strategies and current applications.

V. Aim of the course

To provide hands-on experience to different biochemical techniques commonly used in research along with the knowledge on principles and the instrumentation.

No.	Blocks	Units
1.	Separation techniques	1. Chromatography techniques
		2. Electrophoretic technique
		3. Hydrodynamic methods
		4. Centrifugation
2.	Spectroscopic techniques	1. Spectrophotometry
		2. Mass spectroscopy
		3. Atomic absorption spectrophotometry
3.	Microscopy	1. Microscopic techniques
4.	Tracer, imaging, immunochemical and other techniques	1. Tracer techniques
		2. Imaging techniques
		3. Immunochemical techniques
		4. Other techniques

VI. Theory

Block 1: Separation Techniques

Principles and applications of separation techniques.

Unit 1: Chromatography techniques (4 Lectures)

Principles and applications of paper, thin layer, gel filtration, ion-exchange, affinity, column & HPTLC, GC, HPLC and FPLC.

Unit 2: Electrophoretic technique (2 Lectures)

General principles,paper and gel electrophoresis, native and SDS-PAGE, 2D-PAGE, capillary electrophoresis.

Unit 3: Hydrodynamic methods (2 Lectures)

Hydrodyanmic methods of separation of biomolecules such as viscosity and sedimentation velocity, - their principles.

Unit 4: Centrifugation (2 Lectures)

Basic principles of sedimentation, type, care and safety aspects of centrifuge preparative and analytical centrifugation.

Block 2: Spectroscopic Techniques

Unit 1: Spectrophotometry (3 Lectures)

Principles and applications of UV-visible, Fluorescence, IR and FTIR, Raman, NMR and FTNMR, ESR and X-Ray spectroscopy.

Unit 2: Mass spectroscopy (3 Lectures)

MS/MS, LC-MS, GC-MS, MALDI-TOF, applications of mass spectrometry in biochemistry.

Unit 3: Atomic absorption spectrophotometry (2 Lectures)

Principle, function and instrumentation ofatomic absorption spectrophotometry.

Block 3. Microscopy

Unit 1: Microscopic techniques (2 Lectures)

Principles and applications, light, UV, phase contrast, fluorescence and electron microscopy, flow cytometry.

Block 4: Tracer, Imaging, Immunochemical and Other Techniques

Unit 1: Tracer technique (2 Lectures)

Tracer techniques in biology: concept of radioactivity, radioactivity counting methods with principles of different types of counters, concept of á, â and ã emitters, scintillation counters, J-ray spectrometers, autoradiography, applications of radioactive tracers in biology.

Unit 2: Imaging techniques (2 Lectures)

Principles and applications of phosphor imager, MRI and CT scan.

Unit 3: Immunochemical technique (2 Lectures)

Production of antibodies, immunoprecipitation, immunoblotting, immunoassays, RIA and ELISA.

Unit 4: Other techniques (2 Lectures)

Cryopreservation, polymerase chain reaction (PCR), FACS.

VII. Practicals

- Expression of concentration in terms of dilution, molarity, normality, percent expression
- pH measurement and buffer preparation
- Determination of absorption maxima of biomolecules
- Estimation of biomolecules through spectrophotometry and other methods

- Separation of carbohydrates and amino acids by paper chromatography
- Separation and analysis of fatty acids/lipids by GC
- Separation/estimation of biomolecules through HPLC and FPLC
- Separation of proteins using ion exchange, gel filtration and affinity chromatography
- Electrophoretic separation of proteins and nucleic acids
- Centrifugation- differential and density gradient
- (NH4)2SO4 precipitation and dialysis
- Use of radioisotopes in metabolic studies
- PCR
- ELISA
- Western blotting/ Dot blotting

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

At the end of the course, the student will acquire the basic knowledge of the main biochemical methods used in the separation, identification, characterization and analysis of biomolecules.

X. Suggested Reading

- Boyer R. 2011. Biochemistry Laboratory: Modern Theory and Techniques 2nd Edition. Pearson
- Hofmann A and Clokie S. 2010. Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology. 7th edition. Cambridge University Press.
- Sawhney SK and Singh R. 2000. Introductory Practical Biochemistry. 2nd Ed. Narosa
- Katoch R. 2011. Analytical Techniques in Biochemistry and Molecular Biology. Springer
- Boyer R. 2009. Modern Experimental Biochemistry. Fifth impression. Pearson
- Lottspeich F and Engels JW. (Eds). 2018. Bioanalytics: Analytical Methods and Concepts in Biochemistry and Molecular Biology. Wiley-VCH
- Wilson K and Walker J. 2010. Principles and Techniques of Biochemistry and Molecular Biol ogy, 7th Edition. Cambridge University Press

I. Course Title : Immunochemistry

II. Course Code : BIOCHEM 506

III. Credit Hours : 3(2+1)

IV. Why this course?

This is an introduction to the field of immunology with emphasis on the biochemical aspects of the systems. This course is intended to equip the student with the knowledge and understanding of the vertebrate immune system, its component and mechanism of immune responses with specific reference to the human immune defence system and plant immunity

V. Aim of the course

To give an insight into the biochemical basis of immunity

No.	Blocks	Units
1.	Basics of Immunology	1. Introduction to immunology 2. Antibodies 3. The immune responses 4. Immunoregulation and immunological techniques

VI. Theory

Block 1: Basics of immunology

Unit 1: Introduction to immunology (7 Lectures)

History and scope of immunology, antigens, adjuvants, immune system, organs, tissues and cells, immunoglobulins, molecular organization of immunoglobulin. Haptens, ag-ab interaction, plant immunity, proteasome mediated process, plantibodies

Unit 2: Antibodies (5 Lectures)

Classes of antibodies, antibody diversity, theories of generation of antibody diversity, vaccine, monoclonal and polyclonal antibodies, hybridoma, recombinant antibodies, complement system - classical and alternate.

Unit 3: The immune responses (8 Lectures)

Cellular interactions in immune response, major histocompatibility complex, cell mediated immune response, cytokines.

Unit 4: Immunoregulation and immunological techniques (8 Lectures)

Immunoregulation, immunological tolerance, hypersensitivity, mechanisms of immunity, innate resistance and specific immunity, current immunological techniques – elisa, ria, immunoblotting, facs; basics of pcr and hybridization based methods of detection, microarray based detection, multiplexing.

VII. Practicals

- Handling, inoculation and bleeding of laboratory animals
- Preparation of antigens and antisera, natural antibodies
- Carbon clearance test
- Lymphoid organs of the mouse
- Morphology of the blood leucocytes
- Separation of lymphocytes from blood, viable lymphocyte count
- Antigen-antibody interaction,
- Precipitation and agglutination
- Direct and indirect haemagglutination
- Immunoelectrophoresis
- Complement fixation
- Quantitation of immunoglobulins by zinc sulphate turbidity and single radial immunodiffusion
- ELISA
- Western blotting

- Fluorescent Ab test
- Hybridoma technique

VIII. Teaching methods/activities.

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

It is expected that the student should understand and explain the structure, functioning and importance of human immune system in term of health and disease.

Suggested Reading

- Punt J, Stranford S, Jones P and Owen J. 2018 . Kuby Immunology. 8th edition. W. H. Freeman
- Renshaw S. 2016. Immunohistochemistry and Immunocytochemistry: Essential Methods, 2nd Edition. John Wiley & Sons, Ltd.
- Abbas AK, Lichtma AH and Pillai S. 2018. Cellular and Molecular Immunology. 9th edition. Elsevier
- Delves PJ, Martin SJ, Burton DR and Roitt IM. 2017. Roitt's Essential Immunology, 13th Edition. Wiley-Blackwell

I. Course Title : Plant Biochemistry

II. Course Code : BIOCHEM 507

III. Credit Hours : 3(2+1)

IV. Why this course?

Harnessing sunlight, plants produce a diverse array of chemical compounds to survive in challenging ecological niches. Plant-derived metabolites are major sources of human food, fibre, fuel, and medicine. This course covers topics related to plant metabolism and discusses how plants generate carbon and energy sources by photosynthesis and synthesize various compounds through complex networks of metabolic pathways.

V. Aim of the course

To provide an understanding of metabolic processes in plants and the role of different biosynthetic pathways in plant growth and development.

No.	Blocks	Units
1.	Photosynthesis	1. Photosynthetic machinery
		2. Carbon reduction
2.	Conversion of photosynthates	1. Synthesis of major biomolecules
		2. Nitrogen and sulphur metabolism
3.	Growth and development	1. Germination and fruit ripening
		2. Phytohormones
4.	Secondary metabolites	1. Biochemistry of plant secondary metabolites

VI. Theory

Block 1: Photosynthesis

Unit 1: Photosynthetic machinery (3 Lectures)

Structure and function of plant cell and its organelles, phytochromes, chloroplastmorphology structure, structure and chemistry of photosynthetic pigments, light reaction of photosynthesis.

Unit 2: Photosynthesis – the process (4 Lectures)

Carbon reduction in C3, C4 and CAM plants, photorespiration, sucrose-starch interconversion.

Block 2: Conversion of Photosynthates

Unit 1: Synthesis of major biomolecules (3 Lectures)

Biosynthesis of structural carbohydrates, storage proteins and lipids.

Unit 2: Nitrogen and sulphur metabolism (5 Lectures)

Basic concepts of nitrogen and sulphur metabolism: biological nitrogen fixation, nitrate assimilation in plants, sulphur chemistry and function, reductive sulphate assimilation pathway, sulphated compounds.

Block 3: Growth and Develpoment

Unit 1: Germination and fruit ripening (4 Lectures)

Biochemistry of seed germination – stages, requirements, metabolism and mobilization of storage material; Biochemistry of fruit ripening – ripening process, cell wall degrading enzymes, role of ethylene and regulation of ethylene production.

Unit 2: Phytohormones (3 Lectures)

Different classes of phytohormones, their biosynthesis and mode of action.

Block 4: Secondary Metabolites

Unit 1: Biochemistry of plant secondary metabolites (6 Lectures)

Biochemistry and significance of plant secondary metabolites – phenolics, terpenoids, alkaloids, cyanogenic glycosides and glucosinolates, effect of biotic and abiotic factors on plant metabolism and plant defense system.

VII. Practicals

- Fractionation of cell organelles,
- Estimation of starch,
- Assay of ADPG pyrophosphorylase/starch synthase,
- Assay of PAL/SOD
- Assay of PPO/LOX,
- Estimation of individual amino acids,
- Qualitative tests of secondary metabolites (alkaloids, sterols etc.)
- Content and composition of carotenoids, anthocyanin and chlorophylls
- Determination of polyphenols/phenolics

- Fractionation of storage proteins
- Estimation of glucosinolates
- Estimation of cyanogenic compounds.

VIII. Teaching methods/activities

- – Classroom lectures (oral + audio-visual)
- – Assignment (Reading/Writing)
- – Oral presentation by students on specified topics
- – Class room quiz
- – Case study

IX. Learning outcome

Successful completion of this course will provide students with fundamental knowledge of biochemistry and specific knowledge of compounds and biochemical pathways that occur in plants.

X. Suggested Reading

- Buchannan BB, Gruissem W and Jones R.L. (eds.). 2000. Biochemistry and Molecular Biology of Plants. 2nd edition. WILEY Blackwell
- Heldt, H-W. 2010. Plant Biochemistry and Molecular Biology. 4th ed. Oxford University Press
- Goodwin TW and Mercer EI. 2005. Introduction to Plant Biochemistry. 2nd edition. CBS
- Heldt, H-W. and Piechulla, B. 2010.Plant Biochemistry. 4th Edition. Elsevier
- Harinda, Makkeaand Klaus. 2007. Plant Secondary Metabolites. Springer
- Cseke LJ, Kirakosyan A, Kaufman PB, Warber S, Duke JA, Brielmann HL. 2006. Natural Products from Plants. 2ndEdition. CRC Press

I. Course Title : Nutritional Biochemistry

II. Course Code : BIOCHEM 509

III. Credit Hours : 3(2+1)

IV. Why this course?

Nutritional biochemistry deals with the structural and functional characteristics of macro and micronutrients in food consumed by humans. The course will expand understanding of the biological roles of nutrients and their metabolism using basic knowledge in physiology, biochemistry, cell biology and molecular biology. It will integrate information on the roles of nutrients in nutrition and health.

V. Aim of the course

To impart knowledge regarding the biochemical aspects of various nutrients and their interactions in foods during processing, storage and deterioration.

No.	Blocks	Units
1.	Nutritional biochemistry	1. Fundamentals of human nutrition
2.	Biochemical functions of nutrients	
3.	Bioavailability of nutrients	
4.	Food sensitivity	

VI. Theory

Block 1: Nutritional Biochemistry

Unit 1: Fundamentals of human nutrition (7 Lectures)

Fundamentals of human nutrition, concept of balanced diet, biochemical composition, energy and food value of various food grains (including cereals, pulses, oilseeds), fruits and vegetables. Physico-chemical, functional and nutritional characteristics of carbohydrates, proteins and fats and their interactions (emulsions, gelation, browning etc.). Digestion and absorption, digestive secretions, their characteristic features and control, protection of microflora of the GI tract

Unit 2: Biochemical functions of nutrients (7 Lectures)

Biochemical functions of nutrients, macro- and micronutrients- carbohydrates, fats and proteins, vitamins, water soluble and fat soluble vitamins, mineral and phytonutrients, prebiotics and probiotics, enzymes and metabolic protein factors, cofactor role, electrolytic function, constituents of skeletal tissues, interrelationship in nutrient functions, mineral deficiency diseases; nutraceuticals, antinutritional factors, biochemistry of postharvest storage.

Unit 3: Bioavailability of nutrients (7 Lectures)

Factors affecting bioavailability of nutrients, biological value of proteins; effect of cooking, processing and preservation of different food products on nutrients, energy- and micronutrient malnutrition, deficiency diseases of macro and micronutrients.

Unit 4: Food sensitivity (7 Lectures)

Food sensitivity: immunologically mediated food sensitivity, nature and properties of antigens in foods, mechanism of induction of all allergic reactions, diagnostic tests for food, hypersensitivity, non-immunologically mediated food sensitivity, food sensitivity due to metabolic diseases, gastrointestinal diseases, food additives, pharmacologic agents, food toxins and poisonous and psychological factors.

VII. Practicals

- Estimation of amylose and amylopectin
- Estimation of resistant starch
- Estimation of ù3, ù6 and trans fatty acid
- Estimation of phenols in plant tissue/sample
- Estimation of carotenoids
- Estimation of amylase, trypsin and chymotrypsin inhibitor activities
- Estimation of Vitamin C in fruits
- Estimation of reducing & non reducing sugar in fruits
- Estimation of protein contents
- Estimation of dietary fibre
- Determination of limiting amino acids
- Estimation of phytate/ oxalate
- Estimation of total antioxidant activity by different methods
- Estimation of curcumin.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

On successful completion of this course students should be able to critically analyse and evaluate concepts in nutritional biochemistry that are important for an understanding of human nutrition, provide nutritional advice based on sound scientific findings, discuss the efficacy and appropriate use of functional foods and critically evaluate nutrition information appearing in popular magazines and other forms of media.

X. Suggested Reading

- Damodaran S. and Parkin KL (ed.) 2017. Fennema's Food Chemistry. CRC Press
- Gibney MJ, Lanham-New SA, Cassidy, A and Voster HH (ed.) 2009. Introduction to Human Nutrition. Wiley-Blackwell
- Trueman, P. 2007. Nutritional Biochemistry. MJP Publishers
- CoX, C. 2015.Nutritional Biochemistry: Current Topics in Nutrition Research. Apple Academic Press Inc.
- Haugen, S. and Meijer, S. 2010. Handbook of Nutritional Biochemistry: Genomics, Metabolomics & Food Supply. Nova Science Publishers Inc.

COMPUTER APPLICATION

M.Sc. (Agri) in Computer Application

Course Code	Course Title	Credit Hours
MCA 552	Object Oriented Programming	3(2+1)
MCA 553	Design And Analysis of Algorithms	3(2+1)
MCA 562	System Software and Programming	3(2+1)
MCA 563	Internet Technologies	2(1+1)
MCA 564	Bioinformatics Computing	2(1+1)
MCA 565	Soft Computing Techniques	2(1+1)
MCA 575	Data Warehousing and Data Mining	3(2+1)

Course Contents
M.Sc. (Agri) in Computer Application

I. Course Title : Object Oriented Programming

II. Course Code : MCA 552

III. Credit Hours : 3(2+1)

IV. Aim of the course

This is a course on Java that aims at exposing the students to understand basic concepts of object oriented design and to write computer programs for problem solving using object oriented.

V. Theory

Unit I

Introduction to Objected Oriented Programming(OOP), Introduction to C++, data types in C++, Compilation and execution of C++; data types, control flow, input/ output operations, interaction with file systems – reading, writing and appending.

Unit II

Strings, string manipulations, Arrays, functions, scope of variables, structures in C++.

Unit III

Classes, data members, member functions, this Pointer, Friends, Friend Functions, Friend Classes, Constructors, destructors.

Unit IV

Operator Overloading, dynamic binding, parametric polymorphism. Inheritance, inheritance and dynamic binding, multiple inheritance.

Unit V

New Approaches to programming – Model-View-Controller (MVC) architecture, Single page applications.

VI. Practical

- Case studies using object oriented analysis and design (OOAD);
- Creation of classes with features - overloading, inheritance, data abstraction, polymorphism and Implementation of a case study.

VII. Suggested Reading

- Arnold K and Gosling J. 1996. The Java Programming Language. The Java Series. Addison Wesley.
- Bergin J. 1994. Data Abstraction: The Object-Oriented Approach Using C++. McGraw Hill.
- Holzner S. 1997. The Visual C++ Programming Language. Prentice Hall of India.
- Johnsonbaugh R and Kalin M. 1995. Object Oriented Programming in C++. Prentice Hall.
- Khoshafian S and Abnous R. 1995. Object Orientation Concepts, Languages, Databases, User Interfaces. JohnWiley.
- Sengupta S and Korobkin C.P. 1994. C++ Object Oriented Data Structures.Springer.

- Stroustrup B. 1997. The C++ Programming Language. Addison Wesley.
- Troelsen A. 2005. Pro C# 2005 and the .NET 2.0 Platform. 3rd Ed. Apress.
- Kothari D.P. 2013. Object Oriented Approach using C++

I. Course Title : Design and Analysis of Algorithms

II. Course Code : MCA 553

III. Credit Hours : 3(2+1)

IV. Aim of the course

This course provides a theoretical foundation in designing algorithms. The focus is on the advanced analysis of algorithms and on how the selections of different data structures affect the performance of algorithms.

V. Theory

Unit I

Algorithm Analysis – Time Space Tradeoff – Asymptotic Notations – Conditional asymptotic notation – Removing condition from the conditional asymptotic notation - Properties of big-Oh notation – Recurrence equations – Solving recurrence equations – Analysis of linear search.

Unit II

Divide and Conquer: General Method – Binary Search – Finding Maximum and Minimum – Merge Sort – Greedy Algorithms: General Method – Container Loading– Knapsack Problem.

Unit III

Dynamic Programming: General Method – Multistage Graphs – All-Pair shortest paths – Optimal binary search trees – 0/1 Knapsack – Travelling salesperson problem.

Unit IV

Backtracking: General Method – 8 Queens problem – sum of subsets – graph coloring – Hamiltonian problem – knapsack problem.

Unit V

Graph Traversals – Connected Components – Spanning Trees – Biconnected components – Branch and Bound: General Methods (FIFO & LC) – 0/1 Knapsack problem – Introduction to NP-Hard and NP-Completeness.

VI. Practical

- Solving recurrence equations, Analysis of linear search,
- Programming Divide and Conquer Algorithms and their analysis,
- Programming Greedy Algorithms and their analysis,
- Implementing Dynamic Programming and their analysis,
- Implementing Backtracking examples,
- Implementing Graph Traversals,
- Implementing Spanning Trees.

VII. Suggested Reading

- Alfred V. Aho, John E. Hopcroft and Jeffrey D. Ullman. 1999. The Design and Analysis of Computer Algorithms. Pearson Education.
- Cormen, T.H., C.E. Leiserson, R.L. Rivest, and C. Stein. 2003. Introduction to Algorithms. Prentice Hall of India, New Delhi.
- Horowitz E, Sahni S and Rajasekaran S. 2007. Computer Algorithms/ C++. Universities Press.

I. Course Title : System Software and Programming

II. Course Code : MCA 562

III. Credit Hours : 3(2+1)

IV. Aim of the course

This is a course on System Software and Programming that aims at exposing the students to understand operating systems and its functions and to design and write simple low level programming.

V. Theory

Unit I

Systems software-introduction, system specific features; Operating Systems and its functions – device management, process management, memory management, file system management, security.

Unit II

Users, directory, files, file access rights; Terminal Controls and signals; Modularization and program assembly – Interfaces, APIs, header files, libraries, shared objects, dynamic and static links.

Unit III

Input/output at System Level – sequential and random access; indexes.

Unit IV

Memory Management –Allocating and deallocating memory; Threads, spawning processes, network access, sleep, Inter Process communications – pipes, shared memory, sockets, secured sockets, Certificates.

Unit V

Object oriented software design; Generic and reusable classes, Debugging and testing of programs

VI. Practical

- Low Level programming for input/output interface, memory, threads, listening and responding,
- Programming constructs, control statements: branching and looping, file operations,
- Creation of classes with features - overloading, inheritance, data abstraction, polymorphism and a case study using and Object oriented language.

VII. Suggested Reading

- Ken A and Gosling, J. 1996. The Java Programming Language. The Java Series. Addison Wesley.
- Balaguruswamy, E. 2019. Programming with ANSI C. Tata McGraw Hill, New Delhi.
- Balaguruswamy, E. 2017. Programming with Object Oriented Programming using C++. Tata McGraw Hill, New Delhi.
- Bergin, J. 1994. Data Abstraction: The Object-Oriented Approach Using C++. McGraw Hill.
- Sethi, R. 1996. Programming Language Concepts. Addison Wesley.
- Stroustrup, B. 1997. The C++ Programming Language. Addison Wesley.

I. Course Title : Internet Technologies

II. Course Code : MCA 563

III. Credit Hours : 2(1+1)

IV. Aim of the course

The main objective of the course is to introduce the whole range of web technologies. Through the various examples, the course will describe how to design a specific page, dynamic web pages, forms and frames and interaction with adatabase.

V. Theory

Unit I

World Wide Web – Web pages, Web Sites, Web Servers; Intranet and Extranet Concepts; Hyper Text Markup Language (HTML); Building static dynamic web pages.

Unit II

Web application architecture – (ASP.NET/Java) – Web Forms, Server Side Controls, handling events, Validation, JQuery

Unit III

Database Connectivity, read, write, update databases using web forms; data bound controls, sessions, session handling

Unit IV

Authentication of users, Personalization, Roles, role based access

Unit V

Using external libraries/ controls; Ajax, Jquery; Data Exchange – XML, JSON; Creating web services

VI. Practical

- Designing static website with features like tables, hyperlink among pages, pictures, frames and layers;
- Client side scripting for user interface validation;
- Server side scripting for database interaction;
- Designing of information system.

VII. Suggested Reading

- Ayers D, Bergsten H, Bogovich M, Diamond J, Ferris M, Fleury M, Halberstadt A, Houle P, Mohseni P, Patzer A, Philips R, Li S, Vedati K, Wilcox M and Zeiger S. 1999. Professional Java Server Programming. Wrox Press Ltd.
- Buest C and Allamaraju S. 2007. Professional Java Server Programming: J2EE 3rd Ed.
- Boudreaux 2005. PHP 5: Your Visual Blueprint for Creating Open Source, Server-side Content. (Visual Blueprint). Visual.
- Ellis M.D. 2007. ASP.NET AJAX Programming Tricks. Magma Interactive.
- Esposito D. 2007. Introducing Microsoft ASP. NET AJAX (Pro-Developer). Microsoft Press.
- Evjen B, Hanselman S and Rader D. 2008. Professional ASP.NET 3.5: In C# and VB (Pro grammer to Programmer). Wrox Press Ltd.
- Haefel-Monson R. 2003. Enterprise Java Beans. O'Reilly & Associates.
- Naughton P and Schildt H. 2001. The Complete Reference, Java 2. Tata McGraw Hill.
- Neimke D. 2006. ASP.NET 2.0 Web Parts in Action: Building Dynamic Web Portals (In Action). Manning Publ.
- Walther S. 2008. ASP.NET 3.5 Unleashed. Sams.

I. Course Title : Bioinformatics Computing

II. Course Code : MCA 564

III. Credit Hours : 2(1+1)

IV. Aim of the course

The aim of the course is to introduce modern computational practices in bioinformatics at the algorithmic level that will train the students to complement researchers with biological background.

V. Theory

Unit I

The Central Dogma, Review and Utilization of Biological Databases.

Unit II

Overview of Algorithms: Pattern Matching, Biological Motivation Naïve Algorithm.

Unit III

Pre-processing: Suffix trees Time and Space Considerations. Approximate Pattern Matching: Sequence Comparisons, Dot Plots. Sequence Alignment: Dynamic Programming, Global and Local Alignments Scoring Matrices, BLAST, FASTA Parameters.

Unit IV

Similarity and Distance: PAM & BLOSUM matrices, Heuristic Approaches.

Unit V

Exhaustive Search Fragment Assembly: DNA Sequencing, Greedy Algorithms, Sequencing by Hybridization Fragment Assembly.

Unit VI

Graph Algorithms, Overlap Graphs, and Hamiltonian Path Wrap-up.

VI. Practical

- Suffix trees: Time and Space Considerations;
- Approximate Pattern Matching: Sequence Comparisons, Dot Plots;
- Sequence Alignment: Dynamic Programming, Global and Local Alignments Scoring Matrices, BLAST, FASTA Parameters;
- Similarity and Distance: PAM & BLOSUM matrices,
- Heuristic Approaches and Exhaustive Search Fragment Assembly: DNA Sequencing, Greedy Algorithms, Sequencing by Hybridization Fragment Assembly,
- Graph Algorithms, Overlap Graphs, and Hamiltonian PathWrap-up.

VII. Suggested Reading

- Bryan B. 2002. Bioinformatics Computing. Prentice Hall.
- Duda R.O., Hart P.E. and Stork D.G. 1999. Pattern Classification. John Wiley.
- Ewens W.J. and Grant G.R. 2001. Statistical Methods in Bioinformatics. Springer.
- Jones N.C. and Pavel A.P. 2004. Introduction to Bioinformatics Algorithms. MIT Press.
- Koskinen T. 2001. Hidden Markov Models for Bioinformatics. Kluwer.
- Krane D.E. & Raymer M.L. 2002. Fundamental Concepts of Bioinformatics. Benjamin / Cummings.
- Krawetz S.A. and Womble D.D. 2003. Introduction to Bioinformatics: A Theoretical and Prac tical Approach. Humana Press.
- Lesk A.M. 2002. Introduction to Bioinformatics. OXford Univ. Press.
- Shortliffe E.H. and Cimino J.J. 2006. Biomedical Informatics: Computer Applications in Health Care and Biomedicine (Health Informatics). Springer.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. Data Mining in Bioinformatics. Springer.

I. Course Title : Soft Computing Techniques

II. Course Code : MCA 565

III. Credit Hours : 2(1+1)

IV. Aim of the course

This course introduces the soft computing techniques and their applications in solving real world problems. The course is dealt with the perspective of using soft computing techniques in machine learning.

V. Theory

Unit I

Introduction to soft-computing tools – Fuzzy Logic, Genetic Algorithm, Neural Networks and Probabilistic Reasoning, Rough Sets.

Unit II

Applications of Fuzzy Logic concepts in Knowledge Management.

Unit III

Optimization problem solving using genetic algorithm.

Unit IV

Neuron as a simple computing element, the perceptron, multilayer neural networks, Neural network approaches in data analysis, design and diagnostics problems; Applications of probabilistic reasoning approaches.

VI. Practical

Classification using Fuzzy Logic, Genetic Algorithm, Neural Networks

VII. Suggested Reading

- Goldberg D.E. 2008. Genetic Algorithms in Search, Optimization, and Machine Learning. Addison Wesley.
- Haykin S. 1998. Neural Networks: A Comprehensive Foundation. Prentice Hall.
- Jang J.R., Sun C and Mizutani E. 1996. Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence. Prentice Hall.
- Kecman V and Kecman V. 2001. Learning and Soft Computing: Support Vector Machines, Neural Networks, and Fuzzy Logic Models. MIT Press.
- Lee K.H. 2005. First Course on Fuzzy Theory and Applications. Springer.
- Mitra S and Acharya T. 2003. Data Mining: Multimedia, Soft Computing, and Bioinformatics. John Wiley.

I. Course Title : Data Warehousing and Data Mining

II. Course Code : MCA 575

III. Credit Hours : 3(2+1)

IV. Aim of the course

The basic objective of this course is to familiarize students about this state of art of setting datawarehouse for business intelligence in relation to agricultural research, development and planning.

V. Theory

Unit I

Concepts and principles of data warehousing; Project management and requirements. Introduction to Data Mining and its Tasks, Data Pre-processing, Data Discretization

Unit II

Dimensional modelling; Data warehousing architecture; System process and process architecture. Classification and Prediction, Decision Tree, Naive Bayes' Classifier.

Unit III

Data warehousing design; Database schema; Data staging. Output and Knowledge Representation, Evaluation and Credibility, Association Rule Mining.

Unit IV

Partitioning strategy; Aggregations; Data marts; Meta data management; OLAP Modelling, Querymanagement. Clustering: Similarity measures, Hierarchical Clustering, k-Means Clustering.

Unit V

Data warehouse security; Backup and recovery; Building end-user Applications; Capacity planning; Testing the warehouse.

Unit VI

Implementation and maintenance of data warehouse; Case study.

V. Practical

- Data warehouse design, selection of schema;
- Normalization and renormalization;
- Query planstrategy;
- Performance tuning, backup and recovery of data warehouse;
- Dynamic reports and OLAP Reports.
- Introduction to Data Mining software,
- Data Pre-processing, Discretization, Decision Tree: D3,Naïve Bayes' Classifier,
- Association Rule Mining: Apriori Algorithm,
- Clustering: Hierarchical Clustering, K-Means.

VI. Suggested Reading

- Gupta, G.K. 2014. Introduction to Data Mining with Case Studies. Prentice Hall of India, New Delhi.
- Han, J and Kamber, M. 2006. Data Mining: Concepts and Techniques. Morgan Kaufman.
- Inmon, B. 2005. Building the Data Warehouse. John Wiley.
- Kelly, S. 1997. Data Warehousing in Action. John Wiley.
- Kimball, R. 2000. The Data Webhouse Toolkit: Building the Web-Enabled Data Warehouse. John Wiley.
- Kimball, R. 2004. The Data Warehouse ETL Toolkit: Practical Techniques for Extracting, Clean ing, Conforming, and Delivering Data. John Wiley.
- Kimball, R. 2005. The Microsoft Data Warehouse Toolkit: With SQL Server 2005 and the Microsoft Business Intelligence Toolset. John Wiley.
- Kimball, R. 2008. The Data Warehouse Lifecycle Toolkit: Practical Techniques for Building Data Warehouse and Business Intelligence Systems. John Wiley.
- Kimball, R and Ross M. 2013. The Data Warehouse Toolkit: The Complete Guide to Dimen sional Modeling, John Wiley
- Lee, K.H. 2005. First Course on Fuzzy Theory and Applications. Springer.

MICROBIOLOGY

Course Title with Credit Load

M.Sc. (Agri) in Microbiology

Course Code	Course Title	Credit Hours
MICRO 501	Techniques in microbiology	2(0+2)
MICRO 502	Principles of microbiology	3(3+1)
MICRO 503	Microbial physiology and metabolism	4(3+1)
MICRO 504	Microbial genetics.	3(2+1)
MICRO 505	Soil microbiology	3(2+1)
MICRO 506	Microbial biotechnology	3(2+1)
MICRO 507	Food microbiology	3(2+1)
MICRO 508	Bacteriophages	2(1+1)
MICRO 509	Environmental microbiology	3(2+1)
MICRO 510	Industrial microbiology	3(2+1)
MICRO 511	Biofertilizer technology	3(2+1)
MICRO 512	Cyanobacterial and algal biotechnology	2(2+0)

Course Contents
M.Sc. (Agri) in Microbiology

Course Title : Techniques in Microbiology
Course Code : MICRO 501
Credit Hours : 2(0+2)

Why this course?

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

Aim of the course

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

The course is organized as follows:

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

Practicals

- Awareness about lab safety measures
- Study of general microbiological equipment, cleaning of glassware and apparatus for laboratory use
- Methods of sterilization used in microbiology laboratory
- Use of simple techniques in laboratory (Colorimetry, Centrifugation, electrophoresis and chroma tography)
- Types of culture media
- Isolation techniques and direct microscopic count
- Environmental factors affecting bacterial growth: physical chemical, temperature, pH, osmotic pressure, light (UV) and bacteriostatic agents. Bacteriology of air, water, and soil.
- Characteristics of important types of micro-organisms: major functional groups of bacteria, lactic acid, spore forming and coliforms bacteria, fungi, yeast and mold.

- Assessment of microbial quality of portable water.
- Working in microscope

Teaching methods/activities

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

Learning outcome

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

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

Suggested Reading

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

Websites

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

Course Title : Principles of Microbiology
Course Code : MICRO 502
Credit Hours : 4(3+1)

Why this course?

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

Aim of the course

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

The course is organized as follows :

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

Theory

Block 1: Scope and History of Microbiology and Microscopy

Unit 1: Scope of microbiology

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

Unit 2: History Routes

The Germ Theory of Disease, Early Studies: Pasteur's Further Contributions, Koch's Contributions, Work Toward Controlling Infections, spontaneous generation theory.

Unit 3: Staining and microscopy

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

Block 2: Evolutionary Link of Prokaryotes

Unit1: Phylogenetic classification

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

Unit2: Methods of sequencing

Use of DNA and r-RNA sequencing in classifications.

Block 3: Microbial Growth, Characterization And Regulation

Unit1: Microbial growth and reproduction

Microbial growth and reproduction-communication, bacteria, yeast and virus growth, Replication, Cultivation methods, Normal micro flora of Human body; Immune response- specific and non-specific host resistance.

Unit 2: Sterilization techniques

Physical and chemical methods of sterilisation.

Unit 3: Nutritional requirements for microbial growth

Classification of microbes: electron, energy and carbon sources.

Practicals

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

Teaching methods/activities

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

Learning outcome

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

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

Suggested Reading

- Brock TD. 2008. Biology of microorganisms (Ed.) Madigan MT, Martinko J M, Dunlap P V, Clark DP, 12th ed. Pearson, New Jersey.
- Pelczar MJ. Jr., Chan, ECS and Kreig NR. 1997. Microbiology, Concepts and Application, 5th edition, Tata McGraw Hill, New York.
- Prescott, L.M., Harley and Klein. 2002. Microbiology 5th Edition, Tata McGraw Hill, New York.
- Bhatia, M.S.2009. Principles of Microbiology. Swastik Publishers., Delhi.
- Madigan, M. T., J. M. Martinko, P.V. Dunlap and D.P. Clark.2001. Brock biology of Micro organism 10th Ed. Pearson Education lnc, USA.
- Singh, U.S and K. Kapoor 2010. Introductory microbiology OXford Book Company., Jaipur
- Tortora, G. J., B.J. Funke and C.L. Case. 2010. Microbiology: an introduction.10th Ed. Ben jamin Cummings., New York
- Davis BD, Dulbecco R, Eisen HN and Ginsberg HS. 1990. Microbiology (4th edition). J.B.Lippincott company, Newyork.
- Alexopoulus CJ and C W. Mims. 1993. Introductory Mycology (3rd edition).Wiley Eastern Ltd, NewDelhi.
- Elizabeth Moore-Landecker. 1996. Fundamentals of the fungi. (4th edition).Prentice Hall Inter national, Inc, London.
- Heritage,J. Evans E.G.V. and Killington, R.A. 1996. Introductory Microbiology. Cambridge University Press.
- Webster J. 1993. Introduction to Fungi.(2nd edition).Cambridge University press,Cambridge.
- Prescott LM, Harley JP and Klein DA. 2006. Microbiology (7th edition) McGraw Hill, Newyork.
- Schaechter M and Leaderberg J. 2004. The Desk encyclopedia of Microbiology. Elseiver Aca demic press, California.
- Nester, E.W., Roberts, C.V. and Nester, M.T. 1995. Microbiology: A human perspective. IWOA, U.S.A.
- Pelczar Jr, M.J. Chan, E.C.S. and Kreig, N.R. 1993. Microbiology, Mc. Graw Hill. Inc, New York.
- Holt JG and Bergey DH. 1994. Bergey's Manual of Determinative Bacteriology (9th Edition), Williams and Wilkins, Baltimore.
- Mara D. and Horan N. 2003. The Handbook of Water and waste water Microbiology. Aca demic Press-An imprint of Elsevier.
- Madigan M T, Bender K S, Buckley HD, Sattley WM, Stahl DA 2017. Brock Biology of Microorganisms - 15th edition. Pearson Education, USA.

Websites

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

I. Course Title : Microbial Physiology and Metabolism
II. Course Code : MICRO 503
III. Credit Hours : 4(3+1)
IV. Why this course?

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

V. Aim of the course

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

The course is organized as follows:

No.	Blocks	Units
1.	Scope of microbial growth and physiology	1. Structure, function and biosynthesis of cellular components
2.	Pathways and their significance; Growthkinetics and nutritional classifications	1. Growth Kinetics, cell cycle, cell division, pathways and fermentation metabolism.
		2. Growth and factors affecting growth and culture systems.
		3. Nutritional classification and spore formation and germination
3.	Enzymes and microbial metabolisms	1. Kinetics and Mechanism of Enzymes
		2. Microbial metabolism
4	Synthesis of macromolecules	1. Biosynthesis of macromolecules

VI. Theory

Block 1: Scope of Microbial Growth and Physiology

Unit 1: Structure, function and biosynthesis of cellular components

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

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

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

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

Unit 2: Growth and factors affecting growth and culture systems

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

Unit 3: Nutritional classification and spore formation and germination

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

Block 3: Enzymes and Microbial Metabolisms Unit 1: Kinetics and Mechanism of Enzymes

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

Unit 2: Microbial metabolism

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

Block 4: Synthesis of Macromolecules

Unit 1: Biosynthesis of macromolecules

Biosynthesis of macromolecules – Synthesis and assembly of cell wall components – Methods of studying biosynthesis - regulation of microbial metabolism.

VII. Practicals

- Use of simple techniques in laboratory (Colorimetry, Centrifugation, electrophoresis and GLC, etc.).
- Determination of viable and total number of cells.
- Measurement of cell size.
- Gross cellular composition of microbial cell. Growth – Factors affecting growth.
- Study of bacterial spores and factors affecting germination.
- Enzyme activity and kinetics – calculating Km and Vmax of enzyme.
- Demonstration of thermos-, meso-, and psychrophilic micro-organisms.
- Production and testing of inducible enzymes in bacteria.
- Sporulation and spore germination in bacteria.
- Protoplasts formation and regeneration.

- Estimation of generation time and specific growth rate for bacteria and yeast.
- Diauxic growth curve.
- Production of synchronous cells.
- Effect of chemicals and environmental factors on bacterial growth.
- Isolation and Identification of reserve food material (Glycogen/ polyphosphates, PHB) from bacteria (Azotobacter, Bacillus megaterium).
- Growth of microorganisms on various carbon and nitrogen sources.

VIII. Teaching methods/activities

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

IX. Learning outcome

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

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

X. Suggested Reading

- Moat, A. G. and J. W. Foster. 2002. Microbial Physiology. John Wiley & Sons, New York, USA. 11th ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- Madigan, M.T, J.M. Martinko and J. Parker. 2006. Brock: Biology of Microorganisms, 11th ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- White, D. 2007. The Physiology and Biochemistry of Prokaryotes, 3rd Edition. OXford Univer sity Press.
- Downs, D. M. 2006. Understanding microbial metabolism. Annual Review of Microbiology 60, 533–559.
- Hosler et al. 2006. Energy Transduction: Proton Transfer Through the Respiratory Complexes. Annual Review of Biochemistry 75, 165-187.
- Okuno et al. 2008. Correlation between the conformational states of F1-ATPase as determined from its crystal structure and single-molecule rotation. PNAS 105(52): 20722-20727.
- Itoh et al (2004) Mechanically driven ATP synthesis by F1-ATPase. Nature 427, 465-468.
- Doelle HW. 1969. Bacterial Metabolism. Academic Press.
- Gottschalk G. 1979. Bacterial Metabolism. Springer Verlag.
- Nelson DL and Cox MM. 2017. Lehninger, Principles of Biochemistry, 4th Edition, W.H.Freeman & Company, 2004. (T1)
- Voet D and Voet JG. 2002. Fundamentals of Biochemistry, Upgrade Edition, Wiley.Journals
- Journal of Bacteriology.
- Advances in Microbial Physiology.
- Soil Biology and Biochemistry.

- Journal of Applied Bacteriology.
- Applied and Environmental Microbiology.
- Microbiology.

Websites

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

I. Course Title : Microbial Genetics

II. Course Code : MICRO 504

III. Credit Hours : 3(2+1)

IV. Why this course?

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

V. Aim of the course

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

The course is organized as follows :

No.	Blocks	Units
1.	Introduction to microbial genetics	1. Historical perspectives of microbial genetics 2. Genome of prokaryote, eukaryote (fungi) and virus 3. Genetic elements - chemical structure and property, enzymes associated and replication 4. Extra-chromosomal DNA in bacteria and eukaryotic cells
2.	Gene expression and regulation	1. Introduction to Gene structure and expression 2. Regulation of gene expression

3.	Mutation, genetic recombination	1. Principles of mutation and types and sequencing 2. Mutagens and their mode of action 3. DNA damage – DNA repair mechanisms in bacteria 4. Genetic recombination in bacteria 5. Gene Sequencing

VI. Theory

Block 1: Introduction to Microbial Genetics

Unit 1: Historical perspectives of microbial genetics

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

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

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

Unit 3 : Geneticelements - chemical structure and property, enzymes associ ated and replication

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

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

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

Block 2: Gene Expression and Regulation

Unit 1: Introduction to gene structure and expression

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

Unit 2: Regulation of gene expression

Regulation of gene expression, negative expression (lac operon and trp operon), positive regu lation (CAMP).

Block 3: Mutation, Genetic Recombination and Sequencing

Unit 1: Principles of mutation and types

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

Unit 2: Mutagens and their mode of action

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

Unit 3: DNA damage - DNA repair mechanisms

DNA damage, DNA repair mechanisms in bacteria.

Unit 4: Genetic recombination in bacteria

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

Unit 5: Gene sequencing

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

VII. Practicals

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

VIII. Teaching methods/activities

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

IX. Learning outcome

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

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

X. Suggested Reading

- Brown TA. 2001. Gene Cloning and DNA Analysis: An Introduction. Fourth Edition. Blackwell Science Inc., Oxford, UK.
- Levin B. 2002. Gene VIII. Oxford Univ. Press, New York. p.990.
- Maloy SR, Cronan JE, Freifelder D. 2008. Microbial Genetics - second edition. Narosa Publising house, New Delhi. p. 525.
- Omoto CK and Lurquin PF. 2004. Genes and DNA: a beginner's guide to genetics and its applications. Colambia University Press, USA.
- Sambrook J, Fritsch EF, Maniatis T. 2000. Molecular Cloning: A laboratory Manuel. Third Edition. Cold Spring Harbor Press, New York.
- Streips UN, Yasbin RE. 2006. Modern Microbial Genetics. Wiley – Liss. John Wiley & sons, Inc. Publication, NY.

- Birge EA. 1981. Bacterial and Bacteriophage Genetics. Springer Verlag.
- Gardner JE, Simmons MJ and Snustad DP. 1991. Principles of Genetics. John Wiley& Sons.
- Lewin B.1999. Gene. Vols. VI-IX. John Wiley & Sons.
- Maloy SR, Cronan JE and Friedfelder D. 2008. Microbial Genetics. Narosa.
- Scaife J, Leach D and Galizzi A 1985. Genetics of Bacteria. Academic Press. William Hayes 1981. Genetics of Bacteria. Academic Press.
- Strips UN, Yasbin RE *2006. Modern Microbial Genetics. Wiley-Liss, NY.

Websites

- http://highered.mcgraw-hill.com/sites/0072552980/student_view0/chapter9/
- http://highered.mcgrawhill.com/sites/0072835125/student_view0/animations.html
- http://cwx.prenhall.com/brock/
- http://www.cliffsnotes.com/sciences/biology/microbiology
- http://plato.acadiau.ca/courses/biol/Microbiology/home.HYPERLINK "http://plato.acadiau.ca/
- courses/biol/Microbiology/home.html"html
- http://www.learner.org/courses/biology/index.html

I. Course Title : Soil Microbiology

II. Course Code : MICRO 505

III. Credit Hours : 3(2+1)

IV. Why this Course?

Understanding the function of the soil ecosystem in relation to ever changing soil conditions is key to understanding the basic mechanisms of soil productivity. This is important in light of the urgency to change agricultural practices and also the problems of xenobiotic compounds in soils. The possible perturbations caused by pollution, intense agricultural practices or changing land use–are of major concern.

The possibility of involvement of nonculturable or minute cell fractions requires innovative research using molecular biological techniques. Information on the effects of different root parts versus bulk soil is interesting. Role of microorganisms in biogeochemical cycles and their interactions decide the nutrients available to crops.

The rhizosphere–the micro environment around plant roots houses intense biological, physical and geochemical activity distinguishing it from surrounding soil. Diversity, distributions, activities and interactions of innumerable organisms affect and are affected by availability of energy and nutrients, soil-water content and rhizosphere redox states. Soil food webs and nutrient cycling in agro ecosystems is of prime concern.

V. Aim of the course

- To help unlock and harness the potential of microorganisms in soil.
- To know the potential benefit of consortia of microorganisms to protect plants from different stresses.
- To study the role of microorganisms in the ecosystem functioning, nutrient cycling and bio geochemical processes including soil enzymes, through their metabolic activity and interactions.

The Course is organized as follows:

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

VI. Theory

Block 1: Developments in Soil Microbiology and Soil Parameters

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

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

Unit 2: Ecology of soil microbiology

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

Block 2: Microbiology and Biochemistry of Plant Parts

Unit 1: Plant parts and soil interface interaction

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

Block 3: Role of Microorganisms in Nutrient Biocycle

Unit 1: Microbial transformation of various nutrients

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

Unit 2: Microbial degradation of organic matter

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

Unit 3: Microbial diversity

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

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

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

VI. Practicals

- Determination of soil microbial population
- Determination of Soil microbial biomass
- Decomposition studies in soil, Soil enzymes
- Measurement of important soil microbial processes such as ammonification, nitrification
- N_2 fixation, S oxidation, P solubilization and mineralization of other micro nutrients
- Study of rhizosphere effect
- Microbial diversity Endophytic microorganisms
- Mycorrhizae, types and role in phosphate mobilization Potassium releasing bacterium
- Microbes in biotic and abiotic stress management

VII. Teaching methods/activities

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

VIII. Learning outcome

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

IX. Suggested Reading

- Paul EA. 2015. Soil Microbiology, Ecology and Biochemistry. Elsevier
- Jan Dirk Van Elsas, Trevors JT and Elizabeth M.H. Wellington, 1997. Modern Soil Microbiol ogy. Marcel Dekker, Inc.
- Paul EA. 2007. Soil Microbiology and Biochemistry 3rd Edition. Academic Press.
- Cardon ZG and Whitbeck JL. 2007. The Rhizosphere An Ecological Perspective. Academic Press.
- Schulz BJE, Boyle CJC and Sieber TN (Edrs). 2006. Microbial Root Endophytes. Pub Springer.
- Magesin R and Schinner F. (Edrs). 2005. Manual of soil analysis monitoring and assessing soil Bioremediation. Pub: Springer.
- Pinton R, Varanini Z and Nannipiers P. The Rhizosphere Biochemistry & organic substances at the soil-plant interface. Pub: CRC Press.
- Prasad TV. 2011. A Text Book of Soil Microbiology. Dominant Publishers & Distributors,New Delhi.
- Mukerji KG, Manoharachary C and Singh J. 2006. Microbial activity n the Rhizosphere. Pub: Springer.

Journals

- European Journal of Soil biology.
- Canadian Journal of Microbiology
- Annual Review of Microbiology

- Journal of the Indian Society of Soil Science.
- Soil Biology and Biochemistry
- Applied soil ecology

Websites

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

II. Course Title : Microbial Biotechnology

II. Course Code : MICRO 506

III. Credit Hours : 3(2+1)

IV. Why this course?

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

V. Aim of the course

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

The course is organized as follows:

No.	Blocks	Units
1.	Scope of Microbial Technology and Fermentation Metabolism	1. Microbial Biotechnology 2. Fermentation Metabolism 3. Fermenter/bioreactor design and 4. operation 5. Fermentation system
2.	Recombinant products	1. Production of recombinant
3.	Microbial conversion and their product formation	1. Industrial production of beverages, acids and solvent 2. New tools and recent advances in microbial biotechnology

VI. Theory

Block 1: Scope of Microbial Technology and Fermentation Metabolism Unit1: Microbial Biotechnology :

Introduction, Scopes, historical development, application and challenges.

Unit 2: Fermentation Metabolism

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

Unit 3: Fermenter/bioreactor design and operation

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

Unit 4: Fermentation system

Types, Batch, Fed batch and continuous fermentation- multistage system. Solid state fermentation, Overproduction of primary and secondary metabolites e.g. amino acids, organic acids, alcohols, enzymes, organic solvents, antibiotics, etc. Immobilization of enzymes; and cells; Scale-up principles; Down-stream processing, etc.

Block 2: Recombinant Products

Unit 1: Production of recombinant

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

Block 3: Microbial Conversion and their Product Formation

Unit 1: Industrial production of beverages, acid and solvent

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

Unit 2: New tools and recent advances in microbial biotechnology

Concept of probiotics and applications of new tools of biotechnology for quality feed/food production; Microorganisms and proteins used in probiotics; Lactic acid bacteria as live vaccines; Bioconversion of substrates, anti-nutritional factors present in feeds; Microbial detoxification of aflatoxins; Microbial polysaccharides :

fermentative production of xanthan gums. Bacterial bioplastics, genetic engineering of microorganisms for the production of poly-3 hydroxyalkanoates. Single cell protein, Bio-insecticides; Bio-fertilizers; Waste as source of energy/food Microbiologically- produced food, colours, and flavours. Retting offlax. Recent advances in microbial biotechnology.

VII. Practicals

- Isolation and maintenance of industrially important microbes
- Production of alcohol
- Production of beer
- Production of citric acid
- Production of lactic acid
- Standardization of physical factors for the higher production of citric acid
- Production and assay of antibiotics
- Production of pullulan
- SCP production
- Study of bioreactors and their operation

VIII. Teaching methods/activities

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

IX. Learning outcome

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

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

X. Suggested Reading

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

Websites

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

I. Course Title : Food Microbiology

II. Course Code : MICRO 507

III. Credit Hours : 3(2+1)

IV. Why this course?

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

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

V. Aim of the course

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

The course is organized as follows:

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

VI. Theory

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

Unit 1: Importance and significance of microorganisms in food

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

Unit 2: Factors of special significance in Food Microbiology

Intrinsic and extrinsic factors influencing microbial growth in foods; Spores and their significance; Indicator organisms and Microbiological criteria.

Unit 3: Microbial spoilage of different types of foods

Microbial spoilage of meat, milk, fruits, vegetables and their products. Food-borne

Block 2: Fermentation and Food Preservation Methods

Unit 1: Food fermentation

Fermented dairy, vegetable, meat products.

Unit 2: Preservatives and preservation methods

Physical methods, chemical preservatives and natural antimicrobial compounds. Biologically based preservation systems. Foods for Specified Health Probiotic bacteria; Bifidus factor. Bacteriocins and their applications; Pre-, probiotics and symbiotics. Microbes as food single cell protein.

Block 3: Food Safety and Quality Management Systems

Unit 1: Advanced techniques in detecting food-borne pathogens and toxins

Food safety and Quality Management Systems- General principles of food safety risk management, Recent concerns on food safety- Safe food alternatives (Organic foods), Good agricultural Practices (GAP), Food Indicators of water and food safety and quality Advanced techniques in detecting food-borne pathogens and toxins. HACCP (Hurdle technology and Hazard analysis. Critical control point) CODEX, FSSAI (Food Safety and Standard Authority of India) systems in controlling microbiological hazards infoods. Food safety regulations

VII. Practicals

- Statutory, recommended and supplementary tests for microbiological analysis of various foods
- Infant foods, canned foods, milk and dairy products, eggs, meat, vegetables, fruits, cereals, surfaces, containers, normal, spoiled, processed, fermented food and water
- Testing of antimicrobial agents
- Analysis of water
- HACCP Plan
- Visit to Food processing Industries

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work in Practical
- Visit to Food processing Industries

IX. Learning outcome

With this course the students are expected to be able to learn

- Important microorganisms in food and their sources.
- Various Factors of special significance in Food Microbiology.
- Biologically based preservation systems of foods.
- Advanced techniques in detecting food-borne pathogens and toxins.

X. Suggested Reading

- Bibek Ray. 1996. Fundamentals of Food Microbiology. CRC Press.
- Frazier W.C. and Westhoff D.C. 1991. Food Microbiology. 3rd Ed. Tata McGraw Hill.
- George J Banwart. 1989. Basic Food Microbiology. AVI. James M Jay. 1987. Modern Food Microbiology. CBS.
- Peppler H.J. and Perlman D. 1979. Microbial Technology. 2nd Ed. Academic Press.
- Adams, M.R., and M. O. Moss 1996. Food Microbiology, New Age International (Rt) Ltd., New Delhi.
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- James M. Jay., Loessner, M.J. and Golden D.A. 2005. Modern Food Microbiology, Seventh edition.
- Verma, L.K. and Joshi, V.K. 2000. Post Harvest Technology of Fruits and Vegetables, Tata McGraw Hill Publication.
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- Doyle, M.P. and Beuchat, L. R. 2007. Food Microbiology- Fundamentals and Frontiers, ASM Press.

- Garbutt, J., 1997. Essentials of Food Microbiology, Armold – International Students edition, London.
- Marriott, N.G. and Gravani R. B. 2006. Principles of Food Sanitation, Food Science text Series, Springer International, New York, USA.

Websites

- https://www.journals.elsevier.com/food-microbiology
- https://www.nature.com/subjects/food-microbiology
- https://www.frontiersin.org/journals/microbiology/sections/food-microbiology
- https://www.sciencedirect.com/journal/food-microbiology

I. Course Title : Bacteriophages

II. Course Code : MICRO 508

III. Credit Hours : 2(1+1)

IV. Why this Course?

Bacteriophages are viruses that infect and reproduce in bacteria. Phages are inherently highly specific towards bacterial hosts. This characteristic has both negative and positive aspects in that it is beneficial in terms of avoiding negative effects on the host microbiota and a hindrance when it comes to detection and elimination of the target pathogen Course is formulated to demonstrate the complete sequence of host parasite reactions and provide a model by which virus –host cell reactions can be postulated for infection in higher plants and animals.

V. Aim of the course

To familiarize the students about phages and phage- bacterial interactions. Bacteriophages have been of intense value in elucidating many biological phenomena, including those concerned with genetics.

The course is organized as follows :

No.	Blocks	Units
1.	Bacteriophages	1. Historical prospective of bacteriophages
		2. Biological processes of phage bacterial interaction
		3. Life cycle of bacteriophages
		4. Biotechnological Genetic manipulation

VI. Theory

Block 1: Bacteriophages

Unit 1: Historical prospective of bacteriophages.

Historical developments and classification of bacteriophages.

Unit 2: Biological processes of phage bacterial interaction

Physiology, biochemistry, enzymology and molecular biology of phage- bacterial interactions.

Unit 3: Life cycle of bacteriophages.

Structure, functions and life cycles of P_2 phage, Lambda phage, M13 phage, OX174 phage.

Unit 4: Biotechnological Genetic manipulation

Phages in the development of molecular biology and genetic engineering.

VI. Practicals

- Titration of phages and bacteria.
- Absorption of phages.
- Preparation of phage stocks.
- Isolation of new phages and phage resistant bacteria.
- One step growth curve, phage bursts.
- Induction of lambda.
- Complementation of T4rII mutantsetc.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work in Practical

VIII. Learning outcome

With this course the students are expected to be able to learn

– About different phages and phage- bacterial interactions.
– Intensible value Bacteriophage in elucidating many biological phenomena, including those con cerned with genetics.
– Development of molecular biology and genetic engineering

IX. Suggested Reading

- Birge EA. 2000. Bacterial and Bacteriophage Genetics. Springer-Verlag. Mathew CK. 1972.Bac teriophage Biochemistry. Am. Chemical Soc.
- Mathew CK, Kutter EM, Mosig G & Berget P. 1988. Bacteriophage T4. Plenum Press.
- Nancy T and Trempy J. 2004. Fundamental Bacterial Genetics. Blackwell. Stent SG. 1963.Mo lecular Biology of Bacterial Viruses. WH Freeman and Co.
- Winkler J, Ruger W and Wackernagel W. 1979. Bacterial, Phage and Molecular Genetics - An Experimental Course. Narosa.
- Winkler U and Rugr W. 1984. Bacteria, Phage and Molecular Genetics. ALA.

Websites

- https://www.nature.com/scitable/definition/bacteriophage-phage-293
- https://www.phe-culturecollections.org.uk/news/nctc-news/the-rise-and-rise-of-
- bacteriophages. aspxhttps://www.khanacademy.org/science/biology/biology-of-viruses/virus-bi ology/a/
- bacteriophages

I. Course Title : Environmental Microbiology

II. Course Code : MICRO 509

III. Credit Hours : 3(2+1)

IV. Why this Course?

This course deals with the study of composition and physiology of microbial communities in the environment. Diversity of microbial populations and their important roles in air, water, soils and sediments. Microbial community ecology and interactions with plants and animals. Microbial communities control nutrient cycles and transformation of compounds. Deeper understanding about the beneficial and harmful effects of microbial communities in the environment will help, so this course as been mandated.

V. Aim of the course

The course is designed to introduce students to diverse microbial population and their important roles in environmental processes in air, water, soils and sediments.types of microorganisms found in the air, terrestrial and aquatic environments. Interaction of microbial communities with plants and animals. Geochemically and environmentally significant processes that are contributed by the activities of microorganisms. Methods that are used to identify and enumerate bacteria in natural environments and also how specific microbial activities. Impact of microbial degradation of organic contaminants and xenobiotics.

The course is organized as follows :

No.	Blocks	Units	
1.	Microbial ecology	1.	Scope of Environmental microbiology and Ecological Niche
		2.	Microorganisms and their natural habitats
		3.	Extremophiles
2.	Microbial interaction	1.	Biogeochemical cycles
		2.	Waste water and solid waste treatment
		3.	Microbial upgradation in fossil fuels and interaction in rumen and gastrointestinal tract

VI. Theory

Block 1: Microbial Ecology

Unit 1: Scope of Environmental microbiology and Ecological Niche

Scope of environmental microbiology, Microbial ecology: Microbial evolution and biodiversity – Ecological niches – Definitions, biotic and abiotic environment. Environmental segments. Composition and structure of environment. Concept of biosphere, communities and ecosystems. Ecosystem characteristics, structure and function. Food chains, food webs and trophic structures. Ecological pyramids.

Unit 2: Microorganisms and their natural habitats

Microorganisms and their natural habitats: Aeromicrobiology, Astrobiology, Methane and chlorates on Mars, terrestrial analogues. Biofilms and microbial mats, Aquatic ecosystems- Public Health Microbiology.

Unit 3: Extremophiles

Extremophiles: Definition and ecological aspects. Thermophiles, xerophiles, Psychrophiles, Piezophiles, Alkaliphiles, Acidophiles- Halophiles and Barophiles. Environmental Distribution and Taxonomic Diversity, Physiology, Adaptive mechanisms, Enzymes, Applications.

Block 2: Microbial Interaction

Unit 1: Biogeochemical cycles

Biogeochemical cycling and its consequences. Global environmental problems.

Unit 2: Waste water and solid waste treatment

Microbiology of wastewater and solid waste treatment: - Waste-types-solid and liquid waste characterization, physical, chemical, biological, aerobic, anaerobic, primary, secondary and tertiary treatments. Anaerobic processes-Bioremediation of nuclear wastes. Bioconversion of Solid Waste and utilization as fertilizer. Bioaccumulation of heavy metal ions from industrial effluents. Biomining. Microbiology of degradation of considerations, decay behavior.

Unit 3: Microbial upgradation in fossil fuels and interaction in rumen and gastrointestinal tract.

Microbial upgradation of fossil fuels and coal gas. Microbial interaction in rumen and gastrointestinal tract.

VII. Practicals

- Determination of indices of pollution by measuring BOD/COD of different effluents.
- Analysis of natural waters.
- Quality control tests, waste treatment and anaerobic digestion; Demonstration of waste water treatment processes such as activated sludge processes, biofilter and fluidized bed process.
- Bacterial reduction of nitrate from ground waters.
- Isolation and purification of degradative plasmid of microbes growing in polluted environments.
- Recovery of toxic metal ions of an industrial effluent by immobilized cells.
- Utilization of microbial consortium for the treatment of solid waste [Municipal Solid Waste]
- Biotransformation of toxic metal ions into non-toxic metals ions.
- Microbial dye decolourization/adsorption.
- Biotrap based isolation of selective functional microbes.
- Thermophlic enzyme in biomass deconstructions.
- Halophilic microbes from salt lake-Pesticide degradation by microbes

VIII. Teaching methods/activities

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

IX. Learning outcome

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

- Appreciate the diverse microbial communities in environment and will be able to isolate and enumerate them from different environment.
- Realise the significance of microbial communities in biogeochemical cycles and their beneficial aspects to plants.
- Role of microorganism which are involved for bioremediation of harmful xenobiotic compounds.

X. Suggested Reading

- Campbell R. 1983. Microbial Ecology. Blackwell.
- Hawker LE & Linton AH. 1989. Microorganisms Function, Form and Environment. 2nd Ed. Edward Arnold.
- Richards BN. 1987. Microbes of Terrestrial Ecosystem. Longman.
- Mitchell R. 1992. Environmental Microbiology. John Wiley & Sons.
- Baker K.H. and Herson D.S. 1994. Bioremediation. McGraw Hill Inc., N.Y.
- Metcalf and Eddy HP. 2004. Waste Water Engineering - Treatment, Disposal and Re-use Inc., Tata McGraw Hill, New Delhi.
- McEldowney S Hardman DJ and Waite S. 1993. Pollution: Ecology and Biotreatment Longman Scientific Technical.
- Mitchell R, and GuJi-Dong. 2010. Environmental Microbiology. John V, Wiley Sons. Inc.
- Waste Water Microbiology 2nd Edition. Bitton. Chemistry and EcotoXicology of pollution. Edited by Des. W. Connell, G.J. Miller. Wiley Interscience Publications.
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- Connell OW and Miller GJ. 1984. Chemistry and Ecotoxicology of pollution. Wiley Interscience Publications.
- Forster CF and John Wase DA. Environmental Biotechnology. Ellis Horwood Ltd. Publication.
- Trivedi RK. 1998. Advances in Waste Water Treatment Technologies. Volumes II and I Global Science Publication.
- Lawrence P, Wacekett C and Hershberger D. 2000. Biocatalysis and Biodegradation: Microbial transformation of organic compounds. ASM Publications.
- Hurst CJ. 2001. A Manual of Environmental Microbiology. 2nd Edition. ASM Publications.

Websites

- http://microbiology.ucsc.edu.
- http://www.asm.org

I. Course Title : Industrial Microbiology
II. Course Code : MICRO 510
III. Credit Hours : 3(2+1)
IV. Why this Course?

The syllabus of industrial microbiology is oriented towards the industrial application of microorganisms and recent microbial products. After studying this course students will know the industrial aspects of microbiology.

V. Aim of the course

To expose the students to the commercial exploitation of microorganisms for production of useful products. Focus will be on understanding of the techniques involved and the application of microorganisms for agribusiness purpose.

The Course is organized as follows:

No.	Blocks	Units	
1.	Basics of Industrial Microbiology	1.	Historical account of microbes in industrial microbiology
		2.	Fermented Microbial products
2.	Bioplastics, Biopolymers & Biofuels	1.	Biocontrol agents and Biopesticides
		2.	Industrial production of Bioplastics and biopolymers
		3.	Production of valuable products

VI. Theory

Block 1: Basics of Industrial Microbiology

Unit 1: Historical account of microbes in industrial microbiology

Introduction to Industrial Microbiology. Sources and characters of industrially important microbes; their isolation, purification and maintenance. types of fermentation and fermenters. Microbial growth kinetics in batch, continuous and fed-batch fermentation process.

Unit 2: Fermented Microbial products

Bioreactors: Types and configuration. Microbiology and production of alcoholic beverages; Malt beverages, distilled beverages, wine and champagne; Commercial production of organic acids like acetic, lactic, citric, and gluconic acids Commercial production of important amino acids (glutamic acid, lysine and tryptophan), vitamins (riboflavin and vitamin A), enzymes, antibiotics and single cell proteins.

Block 2: Bioplastics, Biopolymers and Biofuels

Unit 1: Biocontrol agents and Biopesticides

Biocontrol agents and Biopesticides: Biocontrol agents and their scope in control of plant diseases, nematodes and insect pests. Role of bioagents in sustainable agriculture.

Unit 2: Industrial production of Bioplastics and biopolymers

Introduction & industrial production of Bioplastics: Microorganisms involved in synthesis of biodegradable plastics and microbial pigments and biopolymers.Biosensors: Development of biosensors to detect food contamination and environment pollution. Biofuels: Production of ethanol, biogas and hydrogen from organic residues, fuels from algae; Mushroom cultivation.

Unit 3: Production of valuable products

Genetic engineering of microbes, Role of recombinant microbes in industrial sectors for enhanced production of valuable products. Mechanisms of pesticide degradation by microbes. Biomining: Coal, mineral and gas formation, prospecting for deposits of crude, oil and gas, recovery of minerals from low-grade ores.

VII. Practicals

- Isolation and purification of industrially important microbes (Bacteria, fungus and yeasts)
- Production of industrial compounds such as alcohol, beer, citric acid, lactic acidacetic acids gluconic acid and their recovery
- Demonstration of biogas production
- Production and assay of enzymes, organic acids and pigments
- Mass production of biocontrol agent
- Visit to industries

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work in Practical
– Field visit/Industries/University lab
– Case studies

IX. Learning outcome

After studying this course students will know and will be able to learn

– The applied and industrial aspects of microbiology such as screening of microorganisms, strain improvement, microbial metabolites, fermented microbial products, microbial enzymes, Biofuels using microbes and microbial production of Biopolymers.
– The recent applications of the microbes for the human welfare.

X. Suggested Reading

- Sylvia DM, Fuhrmann JJ, Hartlly PT and Zuberer D. 2005. Principles and Applications of Soil Microbiology. 2nd Ed. Pearson Prentice Hall Edu.
- Waites, M.J., Morgan, N.L., Rockey, J.S. and Higton, G. (2002). Industrial Microbiology: An Introduction. Blackwell Science Publishers.
- Crueger W and Crueger A. Biotechnology: A Text Book of Industrial Microbiology Panima Publishing Corporation.
- Reed G. 1999. Prescott and Dunn's Industrial Microbiology. CBS Publishers.
- Demain AL. 2001. Industrial Microbiology and Biotechnology IInd Edition. ASM Press, Wash ington.
- Stanbury PF, Whitaker W and Hall SJ. 1997. Principles of Fermentation Technology Aditya Books (P) Ltd., New Delhi.
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- Forciniti D. 2008. Industrial Bioseparations: Principles and Practice. 1st Edition, Wiley- Blackwell.
- OkaferN. 2007. Modern Industrial Microbiology and Biotechnology, Scientific Publishers, Enfield, USA.
- Nduka O and Benedict OC. 2018. Modern Industrial Microbiology and Biotechnology, Taylor and Francis 465p.

- ElMansi EMT, Bryce CFA, Dahhou A, Sanchez S, Demain AL, Allman AR. 2012. Fermentation Microbiology and Biotechnology 3rd Ed. CRC Press, Taylor and Francis, Boca Raton.
- Stanbury AF and Whitaker A. 1984. Principles of Fermentation Technology –OXford Pergamon press New York.
- Moses V and Cape RE. 1991. Biotechnology - The Science and the Business Harwood Aca demic Publishers, USA.
- Casida LE Jr. 1989. Industrial Microbiology Wiley Eastern Ltd., N. Delhi.
- Miller BM and Litsky W. 1976. Industrial Microbiology, McGraw Hill Co.,New York 451p.
- Crueger W and Crueger A. 1984. Biotechnology – a Text book of Industrial Microbiology. Science Tech. Inc., Madison.
- Glazer AN and Nikaido HN. 1995. Microbial Biotechnology: Fundamentals of Applied Micro biology, W.H.Freeman Co., New York.
- Demain AL and Solomon MA. 1986. Manual of Industrial Microbiology and Industrial Micro biology, American Society of Microbiology, Washington.
- Atkinson B and Marituna F. 1983. Biochemical Engineering and Biotechnology Handbook, McMillian Publishers.
- Jones DG. 1983. Exploitation of Microorganisms. Chapman & Hall, OXford.
- Peppler HJ and Perlman D. 1979. Microbial technology Vol.1 Fermentation Tecnology, Vol.2, Academic Press.
- Rehm HJ and Reed G. 1995. Biotechnology, a Comprehensive Treatise, 8 Vols. (Reference Book) Verlag Chemie,Wienheim. Also refer Second edition, 12 vols,1995 (Rehm,H.J.: Reed, G.: Puhler,A; Stadler, P Eds)
- Moo-Young Y. 1985. Comprehensive Biotechnology- 5 vols. (Reference Book) Pergamon Press, Oxford.
- Arora DK. 1992. Handbook of Applied Mycology – 5 Vols. (Reference Book) Marcel Dekker, New York.
- Glick BR and Pasternak JJ. 2003. Molecular Biotechnology-principles and applications of re combinant DNA,ASM press,Washington,760 pp. Also consult latest issues of:
- Advances in Applied Microbiology, Biotechnology Advances,
- Biotechnology & Genetic Engineering Reviews,Advances in Biochemical Engineering & Biotech nology, Advances in Microbial Physiology

Websites

- https://www.biomerieux.com/en/industrial-microbiological-control-0
- https://icar.org.in/content/food-and-industrial-microbiology

I. Course Title : Biofertilizer Technology

II. Course Code : MICRO 511

III. Credit Hours : 3(2+1)

IV. Why this Course?

The exploitation of beneficial microbes as a biofertilizer is of prime importance in agriculture sector for their potential role in food safety and sustainable crop production. There is wide gap between nutrient removal and supplies. There is increase in cost of fertilizers due to deplete in the feed stock fossil fuels besides growing concern of environmental hazards due to chemical fertilizers. It is essential to exploit Biofertilizers having functional traits for enhancing plant growth and productivity, nutrient profile, plant defense and protection with special emphasis to its function to trigger various growth- and defense-related genes in signaling network of cellular pathways to cause cellular response and thereby crop improvement.

The syllabus Biofertilizers technology is oriented towards application of biofertilizer to trap atmospheric nitrogen to the soil and convert them into plant usable forms. They also convert the insoluble phosphate forms into plant available forms. They stimulate root growth by producing some hormones and antimetabolites. Improved Plants.

V. Aim of the course

To familiarize the students and farmers with mass scale production of different agriculturally important microorganisms which are being used as biofertilizers for maintaining the soil and plant health for sustaining crop productivity and their importance in organic farming.

The course is organized as follows:

No.	Blocks	Units	
1.	Agriculturally important beneficial microorgansims	1.	Agriculturally important beneficial nitrogen fixing microorganisms.
		2.	Agriculturally important beneficial microorganisms related to phosphorous, potassium, Sulphur and Zinc nutrition
		3.	Agriculturally important beneficial microorganisms having plant growth promoting rhizobacteria
		4.	Agriculturally important biocontrol microbial inoculants
		5.	Economics of biofertilizer production.
2.	Production of Biofertilizer	1.	Production and quality control of biofertilizer

VI. Theory

Block 1: Agriculture Important Beneficial Microorganisms

Unit 1: Agriculturally important beneficial nitrogen fixing microorganisms.

Different agriculturally important beneficial microorganisms: Chemical Vs Biofertilizers: Current Scenario in biofertilizer technology in world-In India-List of biofertilizers-their applications in agriculture. Brief introduction about Agriculturally beneficial microorganisms (free living, symbiotic (rhizobial, actinorhizal), associative and endophytic nitrogen fixers including phosphobacteria, cyanobacteria, their types and importance taxonomic classification, Nitrogen fixing biofertilizers: nodule formation, competitiveness and quantification of N_2 fixed and their use. Mechanism of phosphorous solubilization by photobacteria. BIS standards of biofertilizers

Unit 2: Agriculturally important beneficial microorganisms related to phosphorous, potassium, Sulphur and Zinc nutrition

Different agriculturally important beneficial microorganisms: phosphate solubilizing bacteria and fungi, including mycorrhiza; Mechanism of phosphorous solubilization by phosphobacteria. Bacteria for potassium, Sulphur and Zinc nutrition.

Unit 3: Agriculturally important beneficial microorganisms having plant growth promoting rhizobacteria.

Different agriculturally important beneficial microorganisms: plant growth promoting rhizobacteria. FCO norms and biofertilizer production and usage at national and international levels

Unit 4: Agriculturally important biocontrol microbial inoculants

Different agriculturally important beneficial microorganisms: Biocontrol microbial inoculants. Requirements for establishing bioinoculants production unit Economics of biofertilizers production Constraints in biofertilizers production and usage

Unit 5: Economics of biofertilizer production

Different agriculturally important beneficial microorganisms for recycling of organic waste and compositing, bioremediators and other related microbes.

Block 2: Production of Biofertilizer

Unit 1: Production and quality control of biofertilizer

Different agriculturally important beneficial microorganisms - selection, establishment, competitiveness, crop productivity, soil & plant health, mass scale production and quality control of bio inoculants. Biofertilizer inoculation and microbial communities in the soil. Different formulations of biofertilizers. Advantages and limitations of Liquid formulations.

VII. Practicals

- Isolation of phosphate solubilizing microorganisms.
- Development and production of efficient microorganisms,
- Determination of beneficial properties in important bacteria to be used as biofertilizer, Nitrogen fixing activity, indole acetic acid (IAA), siderophore production etc,
- Bioinoculant production and quality control.
- Population dynamics in broth and carrier materials during storage.
- Development of cultures from starter.
- Preparation of broth for large scale cultivation in fermenter/ large containers. Inoculation and development of culture.
- Mass production of carrier based and liquid biofertilizers. Mass production of important two or three biocontrolagents (Trichoderma viride, Pseudomonas fluorescens and Metarhiziumanisopliae).
- Form, dose and method of application.
- Mass production of AM fungi in pot and root organ culture.
- Quality control and BIS standards.
- Mass production of Azolla and BGA.
- Visit to a biofertilizer production plant

VIII. Teaching methods/activities

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

– Group discussion
– Case Analysis and case studies
– Guest Lectures
– Review of policy documents

IX. Learning outcome

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

– Agriculturally important beneficial microorganisms for fixation of various important elements and compounds.
– Biofertilizer production and usage at national and international levels.
– Requirements for establishing bioinoculants production unit, economics (solid liquid carrier) pro duction, constraints in biofertilizers production and usage.
– A complete exposure to all kinds of agriculture important biofertilizers along with their functions and properties,
– Helps to develop as entrepreneur.

X. Suggested Reading

Books

- Alexander M. 1977. Soil Microbiology. John Wiley.
- Bergerson FJ. 1980. Methods for Evaluating Biological NitrogenFixation. John Wiley & Sons.
- Sylvia DM, Fuhrmann JJ, Hartlly PT and Zuberer D. 2005. Principles and Applications of Soil Microbiology. 2nd Ed. Pearson Prentice Hall Edu.
- Van Elsas JD, Trevors JT and Wellington EMH. 1997. Modern Soil Microbiology. CRC Press.
- Panwar JDS and Jain AK. 2016. Organic farming scope and use of biofertilizers. Pub: NIPA, New Delhi.
- Gaur AC. 2010. Biofertilizers in Sustainable Agriculture, ICAR, New Delhi.
- Chanda P and Srivathsa RSH. 2005. Liquid Biofertilizers. Ministry of Agriculture Department of Agriculture & Cooperation, GOI.
- DeshMukh AM, Khobragade RM and DiXit PP. 2007. Handbook of Biofertilizers & Biopesticides. Oxford Book Company, Jaipur, India.
- Gupta RP, Kalia A and Kapoor S. 2007. Bioinoculants a Step towards Sustainable Agriculture .NIPA, New Delhi.
- Somani LL, Shilkar P and Shilpkar D. 2011. Biofertilizers Commercial Production Technology & Quality Control. AgroPublishing Acadamy, Udaipur.
- Srivastava HS and Singh RP. 1995. Nitrogen nutrition in higher plants. Associated Publishing Company, New Delhi.
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- Vora MS, Shelat HN and Vyas RV. 2013. Handbook of Biofertilizers & Microbial Pesticides.
- Chanda JK. 2008. Biofertilizer Statistics 2006-07. The fertilizer Association of India, New Delhi.

Journals

- Journal of Biofertilizer & Biopesticides
- Journal of Botanical Sciences

Websites

- Biofertilizer in organic Agriculture (www.Journalphytology.com)
- Microbial biofertilizers (www.Boffinaccess.com)
- Biofertilizer as a prospective input for sustainable agriculture in India. http://www.krishisewa.com/articles/organic-agriculture/115-biofertilizers.html
- Handbook of Microbial Biofertilizers M. K. Rai, PhD Editor Pub: Food Products Press, NY.
- Bio fertilisers https://www.worldcat.org/search?q=biofertilisers&fq=dt%3Abks&dblist=638&qt=sort&se= yr&sd=desc&qt=sort_yr_desc

I. Course Title : Cyanobacterial and Algal Biotechnology

II. Course Code : MICRO 512

III. Credit Hours : 2(2+0)

IV. Why this Course?

Cyanobacteria and algal biomass contribute major role in carbon cycle in turn influencing the climate. The blooms of cyanobacteria and algae in different ecosystems is worth exploiting due to their wide biodiversity. They play an important role in agriculture by contributing to the fertility of soil in terms of biomass, biofertilizer, and act as herbicides, insecticides and in bioremediation. Their physiological and biochemical properties disclose their significant potential for colorants, polysaccharides, pharmaceutical & nutraceutical compounds, and valuable biomolecules of industrial importance. With the population explosion and scarcity of land, these can provide better feed stock due to their high protein content, easy cultivation, and versatile growth and easy to harvest. It is challenging for designing bioreactor and utilizes waste waters for growing and harvesting cyanobacteria and algae for these purposes. They are capable of producing and accumulating lipids which can be the source for biodiesel in future.

This course will help the student to understand taxonomy and molecular biology methods of cyanobacteria. The course will give knowledge on cyanobacterial and algal fuels,

V. Aim of the course

The aim is togive exposure on the potential applications of cyanobacteria and algae in Agriculture, Industry and Environment; to inculcate knowledge on algal mass production techniques and their valuable products of commercial importance and to introduce the R&D and entrepreneurial opportunities algae. Students will learn about biodiversity of cyanobacteria and their classification, the biotechnological applications in agriculture – biofertilizers, biocontrol, bioenergy and bioprocessing,their applications in pharmaceuticals, production of pigments, as source of food, etc.

The course is organized as follows :

No.	Blocks	Units
1.	Importance of cyanobacteria and	1. Ecology and evolution of algae and algae cyanobacteria
2.	Physiology and culturing of cyanobacteria and algae	1. Algal pigments, storage products 2. Metabolism of carbon and nitrogen 3. Culturing methods.

3.	Role of cyanobacteria and algae in their products of industrial importance	1.	Importance as fuels, neutraceuticals and agriculture and industrial importance
		2.	Role of algae related to environment

VI. Theory

Block 1: Importance of Cyanobacteria and Algae

Unit 1: Ecology and evolution of algae and cyanobacteria

Introduction to cyanobacteria and algae. Definition, occurrence and distribution, thallus structure, reproduction, life cycles, origin and evolution of cyanobacteria, molecular evolution; role of algae in evolution of land plants and horizontal transfer of genes. Brief classification of algae: different classes, occurrence and distribution.

Block 2: Physiology and Culturing of Cyanobacteria and Algae

Unit 1: Algal pigments, storage products.

Algal pigments, storage products, physiology and metabolism including photosynthesis.

Unit 2: Metabolism of carbon and nitrogen

Ecology of algae –primary colonizers and cycling in soil and water. Cellulardifferentiation and nitrogen fixation, nitrogen metabolism carbon metabolism.

Unit 3: Culturing methods

Algal culturing and cultivation. Culture types, culture conditions, culture vessels, culture media, sterilization, culture methods, synchronous cultures, photobioreactors, algal density and growth, seaweed cultivation.

Block 3: Role of Cyanobacteria and Algae in Agriculture and their Products of Industrial Importance

Unit 1: Importance as fuels, neutraceuticals and industrial importance.

Cyanobacterial and algal fuels, Fine chemicals (restriction enzymes etc.) and nutraceuticals from algae; UV absorbing pigments Industrial products from macro algae - seaweed biotechnology, sustainable aquaculture. Ecology of algae- distribution in soil and water; primary colonizers, carbon sequestration and cycling in soil and water. Cellular differentiation and nitrogen fixation, nitrogen metabolism.

Unit 2: Role of algae related to environment.

Algae in pollution control - as pollution indicators, eutrophication agents and role in Bioremediation and reclamation of problem soils. Cyanobacterial and algal toxins, allelopathic interactions, Algae in global warming and environmental sustainability. Cyanobacteria and selected microalgae in agriculture – biofertilizers &algalization; soil conditioners; reclamation of problem soils.

VII. Teaching methods/activities

- Lecture
- Assignment (reading/writing)
- Publication review
- Student presentation

– Group discussion
– Case analysis and case studies
– Guest lectures

VIII. Learning outcome

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

– Types of cyanobacteria and algae along with their physiological and biochemical properties that provides base for selection for further exploitation of industrial use.
– Algal culturing and cultivation. Culture types, culture conditions, synchronous cultures, photobioreactors, algal density and growth, seaweedcultivation.
– Production of cyanobacterial and algal fuels
– Industrial products from macro algae – seaweed biotechnology, sustainable aquaculture.
– Ecology of algae – distribution in soil and water; primary colonizers, carbon sequestration and cycling in soil and water.

IX. Suggested Reading

- Ahluwalia AS. 2003. Phycology: Principles, Processes and Applications. Daya Publ.
- Barsanti L and Gualtieri P. 2006. Algae: Anatomy, Biochemistry and Biotechnology. Taylor & Francis, CRC Press.
- Carr NG and Whitton BA. 1982. The Biology of Cyanobacteria. Blackwell.
- Herrero A and Flores E. 2008. The Cyanobacteria Molecular Biology,Genomics and Evolution. Calster Academic Press Basic Sciences: Microbiology
- Kumar HD. 2005. Introductory Phycology. East West Press. Linda E Graham & Lee W Wilcox. 2000. Algae. Prentice Hall.
- Andersen RA. 2005. Algal Culturing Techniques. Academic Press.
- Venkataraman LV and Becker EW. 1985. Biotechnology and Utilization of Algae: the Indian Experience. DST.
- Das MK. 2010. Algal Biotechnology. Daya Publishing House.
- Tiwari. 2014. Cyanobacteria: Nature, Potentias and Applications. Daya Publishing House.
- Khattar JIS, Singh DP, Kaur G. 2009. Algal Biology and Biotechnology. I.K. International Publishing HousePvt. Ltd.
- Bhatnagar SK, Saxena A, Kraan S. 2011. Alga Biofuels. Stadium Press (India) Pvt. Ltd.
- Sahoo D and Kaushik BD. 2012. Algal Biotehcnolgoy and Environment. I.K. International Publishing HousePvt. Ltd.

Journals

- Journal of Phycology
- Journal of Applied Phycology
- Frontiers in Microbiology

Websites

- Cyanbacterial and algal Biotechnology
- https://www.worldcat.orgsearch?q=cyanobacterial+and+algal+biotechnology&qt=results page#%2528X0%253Abook%2BX4%253Aprintbook%2529format
- www.cyanosite.bio.purdue.edu

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.bbsrc.ac.uk/organisation/policies/reviews/scientific-areas/1107-algal-research.aspx
- http://asulightworks.com/resources/videos/arizona-center-algae-technology-and-innovation.html

MOLECULAR BIOLOGY AND BIOTECHNOLOGY

Course Title with Credit Load

M.Sc (Agri) in Molecular Biology and Biotechnology

Course Code	Course Title	Credit Hours
MBB 501	Principles of Biotechnology	3(3+0)
MBB 504	Techniques in Molecular Biology I*	3(0+3)
MBB 507	Techniques in Molecular Biology II	3(0+3)
MBB 508	Introduction to Bioinformatics	3(2+1)
MBB 509	Plant Tissue culture	3(2+1)
MBB 511	Molecular Plant Breeding	3(2+1)
MBB 512	IPR, BIO-Safety & Bioethics	2(2+0)
MBB 514	Nano Biotechnology	3(2+1)
MBB 515	Environmental Biotechnology	3(3+0)

Course Contents
M.Sc (Agri) in Molecular Biology and Biotechnology

I. Course Title : Principles of Biotechnology

II. Course Code : MBB 501

III. Credit Hours : 3(3+0)

IV. Aim of the course

- To understand the basics of Molecular biology, plant and microbial Biotechnology
- Importance and applications in agriculture, case studies and success stories
- Public education, perception, IPR and related issues

V. Theory

Unit I (12 Lectures)

History, scope and importance of Biotechnology; Specializations in Agricultural Biotechnology: Genomics, Genetic engineering, Tissue Culture, Bio-fuel, Microbial Biotechnology, Food Biotechnology etc. Basics of Biotechnology, Primary metabolic pathways, Enzymes and its activities.

Unit II (16 Lectures)

Structure of DNA, RNA and protein, their physical and chemical properties. DNA function: Expression, exchange of genetic material, mutation. DNA modifying enzymes and vectors; Methods of recombinant DNA technology; Nucleic acid hybridization; DNA/RNA libraries; Applications of gene cloning in basic and applied research, Plant transformation: Gene transfer methods and applications of GM crops.

Unit III (8 Lectures)

Molecular analysis of nucleic acids -PCR and its application in agriculture and industry, Introduction to Molecular markers: RFLP, RAPD, SSR, SNP etc, and their applications; DNA sequencing, different methods; Plant cell and tissue culture techniques and their applications.Introduction to genomics, transcriptomics, ionomics, metabolomics and proteomics. Plant cell and tissue culture techniques and their applications.

Unit IV (12 Lectures)

Introduction to Emerging topics: Genome editing, gene silencing, Plant microbial interactions, Success stories in Biotechnology, Careers and employment in biotechnology. Public perception of biotechnology; Bio-safety and bioethics issues; Intellectual property rights in biotechnology.

VI. Suggested Reading

- Watson JD, Baker TA, Bell SP, Gann A, Levine M and Losick R. 2014. Molecular Biology of the Gene, 7th edition, Cold Spring Harbor Laboratory Press, New York
- Brown T A. 2010. Gene Cloning and DNA analysis an Introduction 6th edition, Wiley Blackwell
- Primrose SB and Twyman R. 2006. Principles of gene Manipulation 7th edition, Wiley Blackwell
- Singh BD. 2012. Biotechnology: Expanding Horizons 4th edition, Kalyani publisher, New Delhi, India

I. Course Title : Techniques in Molecular Biology I

II. Course Code : MBB 504

III. Credit Hours : 3(0+3)

IV. Aim of the course

- To get a basic overview of molecular biology techniques, good lab practices and recombinant DNA technology
- To get a hands on training in chromatography, protein analysis, nucleic acid analysis, bacterial and phage genetics

V. Practicals

- Good lab practices, preparation of buffers and reagents.
- Principle of centrifugation and spectrophotometry.
- Growth of bacterial culture and preparation of growth curve, Isolation of Genomic DNA from bacteria.
- Isolation of plasmid DNA from bacteria.
- Growth of lambda phage and isolation of phage DNA.
- Isolation and restriction of plant DNA (e.g. Rice / Moong / Mango / Merigold).
- Quantification of DNA by (a) Agarose Gel electrophoresis and (b) Spectrophotometry
- PCR using isolated DNA.
- PAGEGel electrophoresis.
- Restriction digestion of plasmid and phage DNA, ligation, Recombinant DNA construction.
- Transformation of E. coli and selection of transformants
- Chromatographic techniques
  a. TLC
  b. Gel Filtration Chromatography,
  c. Ion exchange Chromatography,
  d. Affinity Chromatography
- Dot blot analysis, Southern hybridization, Northern hybridization.
- Western blotting and ELISA.
- Radiation safety and non-radio isotopic procedure.

VI. Suggested Reading

- Sambrook, J., and Russell, R.W. 2001. Molecular Cloning: A Laboratory Manual 3rd Edition, Cold spring harbor laboratory press, New York.
- Wilson, K., and Walker, J., 2018. Principles and Techniques of Biochemistry and Molecular Biology 8th edition, Cambridge University Press.
- Ausubel FM, Brent R, Kingston RE, Moore DD, Seidman JG, Smith JA and Struhl K. 2002. Short Protocols in Molecular Biology 5th edition, Current Protocols publication.

I. **Course Title : Techniques in Molecular Biology II**

II. **Course Code : MBB 507**

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

IV. **Aim of the course**

- To get a basic overview of molecular biology techniques, good lab practices and molecular markers.
- To get a hands on training in RNAi, microarrays, yeast2 hybrid and immunological techniques.

V. Practicals

Construction of gene libraries (cDNA and Genomics).

- Synthesis and cloning of cDNA.
- Real time PCR and interpretation of data.
- Molecular markers
  - i. RAPD.
  - ii. SSR.
  - iii. AFLP / ISSR and their analysis.
- Case study of SSR markers - construction of linkage map.
- QTL analysis using genotypic data based on SSR.
- SNP identification and analysis.
- Microarray studies and use of relevant software.
- Proteomics
  - i. 2D gels,
  - ii. Mass spectrometry
- RNAi - designing of construct, phenotyping of the plant.
- Yeast 1 and 2-hybrid interaction.
- Generation and screening of mutants.
- Transposon mediated mutagenesis.
- Immunology and molecular diagnostics: Ouchterlony double diffusion, Immunoprecipitation, Ra diation Immunodiffusion, Immunoelectrophoretic, Rocket Immunoelectrophoretic, Counter Cur rent Immunoelectrophoretic,ELISA, Latex Agglutination, Immunohistochemistry.

VI. Suggested Reading

- Wilson, K., and Walker, J. 2018. Principles and Techniques of Biochemistry and Molecular Biology 8th Edition, Cambridge University Press
- Bonifacino, J. S., Dasso, M., Harford, J. B., Liipincott-Schwartz, J., and Yamada, K. M. 2004. ShortProtocols in Cell Biology. John Wiley & Sons, New Jersey
- Hawes, C., and Satiat-Jeunemaitre, B. 2001. Plant Cell Biology: Practical Approach. OXford University Press, Oxford
- Sawhney, S.K., Singh, R. 2014. Introductory Practical Biochemistry, Alpha science international limited

I. Course Title : Introduction to Bioinformatics

II. Course Code : MBB 508

III. Credit Hours : 3(2+1)

IV. Aim of the course

- To get a basic overview of computational techniques related to DNA, RNA and protein analysis.
- To get a hands on training in software's and programs used to analyse, assemble or annotate genomes, phylogenetics, proteomics etc.

V. Theory

Unit I (8 Lectures)

Bioinformatics basics, scope and importance of bioinformatics; Biological databases for DNA and Protein sequences -PIR, SWISSPROT, GenBank, DDBJ, secondary database, structural databases –PDB,SCOP and CATH, Specialized genomic resources, Microarray database.

Unit II (10 Lectures)

Bioinformatics Tools Facilitate the Genome-Wide Identification of Protein-Coding Genes, Sequence analysis, Sequence submission and retrieval system-SEQUIN, BANKit, SAKURA, Webin, Sequence alignment, pair wise alignment techniques, multiple sequence alignment; Tools for Sequence alignment- BLAST and its variants; Phylogenetic analysis- CLUSTAL X, CLUSTAL W, Phylip, Tcoffee

Unit III (10 Lectures)

Sequencing of protein; Protein secondary structure prediction- Chousfasman, GOR Method, Protein 3DStructure Prediction: Evaluation of models- Structure validation and refinement - Ramachandran plot, Force field calculations, SAVES. Protein function prediction- sequence and domain based, Primer designing- principles and methods.Drug discovery, Structure Based Drug Design- Rationale for computer aided drug designing, basic principles, docking, QSAR.

VI. Practical (12 Lectures)

- Usage of NCBI resources
- Retrieval of sequence/structure from databases and submission
- Different Databases, BLAST exercises.
- Assembly of DNA and RNA Seq data
- Annotation of assembled sequences,Phylogenetics and alignment
- Visualization of structures, Docking of ligand receptors
- Protein structure analysis and modeling

VII. Suggested Reading

- Attwood, T.K., and Parry-Smith, D. J. 2004. Introduction to Bioinformatics, Pearson Education (Singapore) Pvt. Ltd.
- David Edwards (Ed.) 2007. Plant Bioinformatics: Methods and Protocols. Humana Press, New Jersey, USA.
- Mount, D. W. 2004. Bioinformatics: Sequence and Genome Analysis, 2nd Revised edition Cold Spring Harbor Laboratory Press, U.S.
- Pevsner J. 2009. Bioinformatics and Functional Genomics, 2nd edition, Wiley-Blackwell.

I. Course Title : Plant Tissue Culture

II. Course Code : MBB 509

III. Credit Hours : 3(2+1)

IV. Aim of the course

- To provide insight into principles of plant cell culture and genetic transformation.
- To get a hands on training in basic plant tissue culture techniques, callusing, micropropagation and analysis.

V. Theory

Unit I (12 Lectures)

History of plant tissue culture, principle of Totipotency; Tissue culture media; Plant hormones and morphogenesis; Direct and indirect organogenesis; Direct and indirect somatic embryogenesis; Applications of planttissueculture; National certification and Quality management of TC plants; Genetic Fidelity testing and Virus indexing methods – PCR, ELISA

Unit II (12 Lectures)

Micropropagation of field and ornamental crops; Virus elimination by meristem culture, meristemtip culture and micrografting; Androgenesis and gynogenesis - production of androgenic and gynogenic haploids - diploidization; Protoplast culture - isolation and purification; Protoplast culture; Protoplast fusion; Somatic hybridization - Production of Somatic hybrids and Cybrids;, Wide hybridization - embryo culture and embryo rescuetechniques; Ovule, ovary culture and endosperm culture.

Unit III (12 Lectures)

Large-scalecell suspension culture - Production of alkaloids and other secondary metabolites-techniques to enhance secondary metabolite production, Somaclonal and gametoclonal variations – causes and applications; Callus culture and in vitro screening for stress tolerance; Artificial seeds, In vitro germplasm storage and cryo-preservation. Commercial Tissue Culture: Case studies and success stories, Market assessment; project planning and preparation, economics, government policies

VI. Practical (12)

- Preparation of stocks - macronutrients, micronutrients, vitamins and hormones, filter sterilization of hormones and antibiotics. Preparation of Murashige and Skoog medium.
- Micro-propagation of plants by nodal and shoot tip culture.
- Embryo culture to overcome incompatibility, Anther culture for haploid production.
- Callus induction in tobacco leaf discs, regeneration of shoots, root induction, role of hormones in morphogenesis.
- Acclimatization of tissue culture plants and establishment in greenhouse.
- Virus indexing in tissue culture plants. (Using PCR and ELISA).
- Plan of a commercial tissue culture unit.

VII. Suggested Reading

- Razdan, M.K. 2003. Introduction to plant tissue culture, 2nd edition, Oxford publications group
- Butenko, R.G. 2000. Plant Cell Culture University Press of Pacific
- Herman, E.B. 2008. Media and Techniques for Growth, Regeneration and Storage, Agritech Publications, New York, USA.

- Bhojwani, S.S and Dantu P. 2013. Plant Tissue Culture – An Introductory Text. Springer Pub lications.
- Gamborg, O.L and G.C. Philips (eds.). 2013. Plant Cell, Tissue and Organ culture-Lab Manual. Springer Science & Business media.

I. Course Title : Molecular Plant Breeding

II. Course Code : MBB 511

III. Credit Hours : 3(2+1)

IV. Aim of the course

- To familiarize the students about the use of molecular biology tools in plant breeding.
- To provide a hands on training in data analysis, diversity analysis and mapping of genes and QTLs.

V. Theory

Unit I (8 Lectures)

Inheritance of qualitative and quantitative traits. Heritability – its estimation, Population structure of self- and cross-pollinated species, Factors affecting selection efficiency. Development of different kinds of segregating populations – F2, F3, BC1F1, BC1F2, BC4F2, RIL (Recombinant Inbred Lines), AIL (Advanced Intercrossed Lines), DH (Di-haploid population), NIL (Near Isogenic lines), NAM (Nested Association Mapping), MAGIC (Multi-parent Advanced Generation Intercross population).

Unit II (8 Lectures)

Causes of sequence variation and its types, Types of molecular markers and development of sequence based molecular markers – RFLP, AFLP, SCARs, CAPS, SSRs, STMS, SNPsInDel and DARTseq; Inheritance of markers, Linkage analysis using test cross, F2, F3, BC1F1, RIL. Construction of genetic map, Mapping genes for qualitative traits; Genotyping by sequencing and high-density chip arrays.

Unit III (8 Lectures)

QTL mapping using structured populations; Association mapping using unstructured populations; Genome Wide Association Studies (GWAS),Principle of Association mapping– GWAS-SNP genotyping methods, DART array sequencing, Illumina's Golden Gate Technology, Genotyping by sequencing methods- Fluidigm; GBS, Illumina Hi seq- Nano pore sequencing, Principles and methods of Genomic Selection, Fine mapping of genes/QTL; Development of gene based markers; Allele mining by TILLING and Eco-TILLING.

Unit IV (8 Lectures)

Tagging and mapping of genes. Bulk segregant and co-segregation analysis, Marker assisted selection (MAS); Linked, unlinked, recombinant, flanking, peak markers. Foreground and background selection; MAS for gene introgression and pyramiding: MAS for specific traits with examples. Haplotype concept and Haplotype-based breeding; Genetic variability and DNA fingerprinting. Molecular markers in Plant variety protection, IPR issues, hybrid purity testing, clonal fidelity testing and transgenic testing.

VI. Practical

- Construction of linkage map.
- QTL analysis using the QTL cartographer and other software.
- SNP data analysis using TASEEL.
- Detection of haplotype block using SNP data - pLinksoftware.
- Genotyping by sequencing methods –Illumina genotyping platform.
- Marker assisted breeding – MABB case studies quality traits in rice/maize.
- Genome Assisted Breeding in model crops, Genomic Selection models usingthe morphological and SNP data

VII. Suggested Reading

- Acquaah, G. 2007. Principles of Plant Genetics and Breeding, Blackwell Publishing Ltd. USA.
- Weising, K., Nybom, H., Wolff, K., and Kahl, G. 2005. DNA Fingerprinting in Plants: Principles, Methods and Applications, 2nd ed. Taylor and Francis Group, Boca Raton, FL.
- Halford, N. 2006. Plant Biotechnology-Current and future applications of genetically modified crops, John Wiley and Sons, England.
- Singh, B. D. and Singh, A. K. 2015. Marker-Assisted Plant Breeding: Principles and Practices Springer (India) Pvt. Ltd.
- Boopathi, NM. 2013. Genetic Mapping and Marker Assisted Selection: Basics, Practice and Benefits. Springer India. p293.

I. Course Title : IPR, Bio-safety & Bioethics

II. Course Code : MBB 512

III. Credit Hours : 2(2+0)

IV. Aim of the course

- To familiarize the students about ethical and biosafety issues in plant biotechnology.
- To provide a hands-on training in data analysis, diversity analysis and mapping of genes and QTLs.

V. Theory

Unit I (10 Lectures)

IPR: historical background in India; trade secret; patent, trademark, design & licensing; procedure for patent application in India; Patent Cooperation Treaty (PCT); Examples of patents in biotechnology-Case studies in India and abroad; copyright and PVP; Implications of IPR on the commercialization of biotechnology products, ecological implications; Trade agreements- The WTO and other international agreements, and Cross border movement of germplasms.

Unit II (8 Lectures)

Biosafety and bio-hazards; General principles for the laboratory and environmental bio-safety; Biosafety and risk assessment issues; handling and disposal of biohazards; Approved regulatory laboratory practice and principles,The Cartagena Biotechnology and Bioinformatics: Molecular Biology and Biotechnology 679 Protocol on biosafety; Biosafety regulations in India; national Biosafety Policy and Law; Regulations and Guidelines related to Biosafety in other countries

Unit III (8 Lectures)

Potential concerns of transgenic plants – Environmental safety and food and feed safety. Principles of safety assessment of Transgenic plants – sequential steps in risk assessment. Concepts of familiarity and substantial equivalence. Risk - Environmental risk assessment – invasiveness, weediness, gene flow, horizontal gene transfer, impact on non-target organisms; food and feed safety assessment – toxicity and allergenicity.Monitoring strategies and methods for detecting transgenics.

Unit IV (6 Lectures)

Field trails – Biosafety research trials – standard operating procedures, labeling of GM food and crop,Bioethics- Mankind and religion, social, spiritual & environmental ethics; Ethics in Biotechnology, labeling of GM food and crop;

Biopiracy

VI. Suggested Reading

- Goel, D. and Parashar, S. 2013. IPR, biosafety, and bioethics.
- Joshi, R. 2006. Biosafety and Bioethics.
- Nambisan, P. 2017. An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology.

I. Course Title : Nano Biotechnology

II. Course Code : MBB 514

III. Credit Hours : 3(2+1)

IV. Aim of the course

Understanding the molecular techniques involved in structure and functions of nano-biomolecules in cells such as DNA, RNA and proteins.

V. Theory

Unit I (8 Lectures)

Introduction to Nanotechnology - Nanomaterials - Self-assembly to artificial assembly for creation of useful nanostructures – Bottoms up and Top down approach (Nano rods, nano cages, nanotubes, quantum dots, nanowires, metal/ polymer-based nanostructures) – Preparation and Characterization of nanoparticles (particle size analyzer, microscopy, viz. electron microscopy, atomic force microscopy, etc).

Unit (8 Lectures)

Cell structure – Bio macromolecules: Types, Structure, Dynamics and interaction with water – Cellular nano machines – cellular transducers, membrane channels, membrane transporters, Membrane motors – Creation of bio-nanostructures (Nano liposomes, Nano micelles, Nanomotors, etc).

Unit III (8 Lectures)

Chemical, physical and biological properties of biomaterials and bio response: biomineralization, biosynthesis, and properties of natural materials (proteins, DNA, and polysaccharides), structure-property relationships in polymeric materials (synthetic polymers and structural proteins); Aerosol properties, application and dynamics; Statistical Mechanics in Biological Systems,

Unit (8 Lectures)

Nanoparticular carrier systems; Micro- and Nano-fluidics; Drug and gene delivery system; Microfabrication, Biosensors, Chip technologies, Nano- imaging, Metabolic engineering and Gene therapy.

VI. Practical

- Isolation of enzymes and nucleic acids involved in biosynthesis of nanomaterials
- Synthesis of Gold/silver Nanoparticles by biogenic methods, Synthesis of micelles and inverse micelles
- Synthesis of Carbon Nano-materials by Chemical Vapor Deposition and Sputtering technique
- Preparation ofthiolate silver nanoparticles, Purification and measurement of carbon nano materials
- Zinc selenide quantum dot preparation, Synthesis of Iron Oxide Nanoparticle
- Thin film preparation by spin coating technique, Synthesis of Nickel metal nanoparticle by urea decomposition method
- Synthesis of Zinc Oxide nanoparticle

VII. Suggested Reading

- Nalwa, H.S. 2005. Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology. American Scientific Publications.
- Niemeyer C.M. and Mirkin C.A. (Eds) 2005. Nanobiotechnology: Concepts Applications and Perspectives, Wiley Inter-science publications.
- Cao, G., and Wang, Y. 2004. Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press.

I. Course Title : Environmental Biotechnology

II. Course Code : MBB 515

III. Credit Hours : 3+0

IV. Aim of the course

To apprise the students about the role of biotechnology in environment management for sustainable eco-system and human welfare.

V. Theory

Unit I (8 Lectures)

Basic concepts and environmental issues; types of environmental pollution; problems arising from high-input agriculture; methodology of environmental management; air and water pollution and its control; waste water treatment - physical, chemical and biological processes; need for water and natural resource management.

Unit II (8 Lectures)

Microbiology and use of micro-organisms in waste treatment; biodegradation; degradation of xenobiotic, surfactants; bioremediation of soil & water contaminated with oils, pesticides and toxic chemicals,detergentsetc; aerobic processes (activated sludge, oxidation ditches, trickling filter, rotating drums, etc); anaerobic processes: digestion, filtration, etc.

Unit III (8 Lectures)

Renewable and non-Renewable resources of energy; energy from solid waste; conventional fuels and their environmental impact; biogas; microbial hydrogen production; conversion of sugar to alcohol; gasohol; biodegradation of lignin and cellulose; biopesticides; biofertilizers; composting; vermiculture etc.

Unit IV (8 Lectures)

Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by microorganisms; global environmental problems: ozone depletion, UV-B, greenhouse effects, and acid rain; biodiversity and its conservation; biotechnological approaches for the management environmental problems.

VI. Suggested Reading

- Evans, G. M. and Furlong, J. C. 2010. Environmental Biotechnology: Theory and Application. 2nd edition, Wiley-Blackwell.
- Jordening HJ and Winter J. 2006. Environmental Biotechnology: Concepts and Applications. Wiley-VCH Verlag.

Nematology

Course Title with Credit Load
M.Sc. in Nematology

Course Code	Course Title	Credit Hours
NEMA 501	Principles of Nematology	3(2+1)
NEMA 502	Principles of TaXonomy	2(2+0)
NEMA 503	Structural Organization of Nematodes	3(2+1)
NEMA 504	Nematode Systematics	3(2+1)
NEMA 505	Nematological Techniques	3(1+2)
NEMA 506	Nematode Diseases of Crops	3(2+1)
NEMA 507	Nematode Biology and Physiology	3(2+1)
NEMA 508	Nematode Ecology	3(2+1)
NEMA 509	Nematode Interactions with Other Organisms	3(2+1)
NEMA 510	Nematode Management	3(2+1)
Nema 511	Beneficial Nematodes	2(1+1)
NEMA 512	Principles of Integrated Pest Management	2(1+1)
NEMA 513	Disease Resistance in Plants	2(2+0)
NEMA 514	Plant Quarantine, Biosafety and Biosecurity	2(2+0)
NEMA 515	IPM in Protected Cultivation	3(2+1)

Course Contents
M.Sc. in Nematology

I. Course Title : Principles of Nematology

II. Course Code : NEMA 501

III. Credit Hours : 3(2+1)

IV. Aim of the course

To project the importance of nematodes in agriculture and impart basic knowledge on all aspects of plant nematology.

V. Theory

Unit I

Characteristics of Phylum Nematoda and its relationship with other related phyla, history and growth of Nematology; nematode habitats and diversity- plant, animal and human parasites; useful nematodes; economic importance of nematodes to agriculture, horticulture and forestry.

Unit II

Gross morphology of plant parasitic nematodes; broad classification, nematode biology, physiology and ecology.

Unit III

Types of parasitism; nature of damage and general symptomatology; interaction of plant-parasitic nematodes with other organisms.

Unit IV

Plant nematode relationships, cellular responses to infection by important phytonematodes; physiological specialization among phytonematodes.

Unit V

Principles and practices of nematode management; integrated nematode management.

Unit VI

Emerging nematode problems, Importance of nematodes in international trade and quarantine.

VI. Practical

- Studies on kinds of nematodes- free-living, animal, insect and plant parasites;
- Nematode extraction from soil;
- Extraction of migratory endoparasites, staining for sedentary endoparasites;
- Examination of different life stages of important plant parasitic nematodes, their symptoms and histopathology.

VII. Suggested Reading

- Dropkin VH. 1980. An Introduction to Plant Nematology. John Wiley & Sons, New York. Maggenti AR. 1981. General Nematology. Springer-Verlag, New York.
- Perry RN and Moens M. 2013. Plant Nematology. 2nd Ed. CABI Publishing: Wallingford, UK. Perry RN, Moens M and Starr J.L. 2009. Root-knot nematodes, CABI Publishing: Wallingford, UK.
- Thorne G. 1961. Principles of Nematology. McGraw Hill, New Delhi.
- Walia RK and Bajaj HK. 2003. Text Book on Introductory Plant Nematology. ICAR, New Delhi.
- Walia RK. and Khan MR. 2018. A Compendium of Nematode Diseases of Crop Plants, ICAR-
- AICRP (Nematodes), IARI, New Delhi.

I. Course Title : Principles of Taxonomy

II. Course Code : NEMA 502

III. Credit Hours : 2(2+0)

IV. Aim of the course

To sensitize the students on the theory and practice of classifying organisms and the rules governing the same.

V. Theory

Unit I

Introduction to history and principles of systematics and importance. Levels and functions of systematics. Identification, purpose, methods-character matrix, taxonomic keys. Descriptions- subjects of descriptions, characters, nature of characters, analogy vs homology, parallel vs convergent evolution, intraspecific variation in characters, polythetic and polymorphic taxa, sexual dimorphism.

Unit II

Classification of animals: Schools of classification- Phenetics, Cladistics and Evolutionary classification. Components of Biological Classification: Hierarchy, Rank, Category and Taxon. Species concepts, cryptic, sibling and etho-species, infra-specific categories. Introduction to numerical, biological and cytogenetical taxonomy.

Unit III

Nomenclature : Common vs Scientific names. International Code of Zoological Nomenclature, criteria for availability of names, validity of names. Categories of names under consideration of ICZN. Publications, Principles of priority, and homonymy, synonymy, type concept in zoological nomenclature. Speciation, anagenesis vs cladogenesis, allopatric, sympatric and parapatric processes.

VI. Suggested Reading

- Blackwelder RE. 1967. Taxonomy - A Text and Reference Book. John Wiley & Sons, New York.
- Kapoor VC. 1983. Theory and Practice in Animal Taxonomy. Oxford & IBH, New Delhi.

- Mayr E. 1971. Principles of Systematic Zoology. Tata McGraw-Hill, New Delhi.
- Quicke DLJ. 1993. Principles and Techniques of Contemporary Taxonomy. Black i.e, London.

I. Course Title : Structural and Functional Organization of Nematodes

II. Course Code : NEMA 503

III. Credit Hours : 3(2+1)

IV. Aim of the course

Familiarization with structural organization of nematode body so as to enable the students to understand biology, physiology and classification of nematodes.

V. Theory

Unit I

Introduction and general organization of nematode body; Morphology and anatomy of nematode cuticle, hypodermis, musculature and pseudocoelom.

Unit II

Digestive system- Structural variations of stoma, oesophagus, intestine and rectum in nematodes.

Unit III

Reproductive system- Variations in female and male reproductive systems, types of reproduction, spermatogenesis and oogenesis.

Unit IV

Types and structure of excretory-secretory systems; nervous system and associated sense organs.

Unit V

Embryogenesis, Cell lineage and postembryonic development; Process of hatching and moulting.

VI. Practical

- Studies on variations in nematode shapes and sizes, morphological details of cuticle, cuticular markings and ornamentation, variations in stoma, oesophagus, rectum;
- Types and parts of female and male reproductive systems, sense organs, and excretory system.

VII. Suggested Reading

- Bird AF and Bird J. 1991. The Structure of Nematodes. Academic Press, New York.
- Chitwood BG and Chitwood MB. 1950. An Introduction to Nematology. Univ. Park Press, Baltimore.
- Maggenti AR. 1981. General Nematology. Springer-Verlag, New York.
- Malakhov VV. 1994. Nematodes: Structure, Development, Classification and Phylogeny. Smithsonian Institution Press, Washington DC.

I. Course Title : Nematode Systematics

II. Course Code : NEMA 504

III. Credit Hours : 3(2+1)

IV. Aim of the course

Understanding concepts in nematode taxonomy, development of skills in the identification of plant parasitic nematodes up to genera and species levels.

V. Theory

Unit I

Gross morphology, principles of nematode taxonomy -levels of taxonomy, systematics vs. taxonomy, morpho-taxonomy, molecular taxonomy, identification, classification, taxonomic categories, taxonomic characters, morphometry, Zoological nomenclature, species concept and speciation (allopatric and sympatric).

Unit II

Taxonomic position of nematodes and their relationships with allied groups; Classification and diagnoses of nematodes up to ordinal rank (Secernentea and Adenophorea)

Unit III

Taxonomy of free living nematodes

Unit IV

Classification of plant parasitic nematodes; Order Tylenchida and diagnoses of its sub-orders, super families, families and important genera; Order Aphelenchida, Dorylaimida and Triplonchida and diagnoses of their important genera.

VI. Practicals

- Collection of soil and plant samples from different habitats, processing and preservation of samples; and preparation of temporary mounts, processing of nematode specimens and permanent mounts;
- Preparation of en face view and TS of nematodes, perineal pattern of root knot nematodes and cone-top structure for cyst nematodes;
- Identification of soil and plant nematodes from nematode suspension and mounted slides;
- Camera lucida drawing of nematodes, measurement of nematodes using traditional as well as image analyzing software;
- Procedures for PCR- Taxonomy.

VII. Suggested Reading

- Ahmad W and Jairajpuri MS. 2010. Mononchida: The Predatory Soil Nematodes, Series: Nematology Monographs and Perspectives, Volume: 7, Brill.
- Geraert E. 2006. Tylenchida. Brill.
- Hunt DJ. 1993. Aphelenchida, Longidoridae and Trichodoridae – their Systematics and Bionomics. CABI, Wallingford.

- Jairajpuri MS and Ahmad W. 1992. Dorylaimida: Free-Living, Predaceous and Plant-Parasitic Nematodes, Brill.
- Mai WF, Mullin PG, Lyon HH and Loeffler K. 1996. Plant-Parasitic Nematodes: A Pictorial Key to Genera, 5th ed., Cornell University Press, London.
- Siddiqi MR. 2000. Tylenchida: Parasites of Plants and Insects. 2nd Ed. CABI, Wallingford.

I. Course Title : Techniques in Nematology
II. Course Code : NEMA 505
III. Credit Hours : 3(1+2)
IV. Aim of the course

Understanding the principles, theoretical aspects and developing skills in nematological techniques.

V. Theory

Unit I

Principles and use of light, scanning and transmission electron microscopes, and other laboratory equipments.

Unit II

Survey and surveillance methods; collection of soil and plant samples; techniques for extraction of nematodes from soil and plant material; estimation of population densities.

Unit III

Killing, fixing, clearing and mounting nematodes; measurements, preparation of perineal patterns, vulval cones of cyst nematodes, en-face views and body section of nematodes.

Unit IV

In-vitro and in vivo culturing techniques of plant parasitic, bacteriophagous, mycophagus and omnivorous nematodes.

Unit V

Staining nematodes in plant tissues; microtomy for histopathological studies; collection of plant root exudates and their bioassay; preparation of plant materials for exhibition.

Unit VI

Application of molecular techniques in Nematology.

VI. Practical

- Collection of soil and plant samples;
- Extraction of nematodes from soil by Baermann funnel, sieving and decanting, elutriation and sugar centrifugal methods;
- Extraction of cysts from soil;
- Extraction of nematodes from plant material;

- Estimation of population densities;
- Staining plant material for nematodes;
- Killing and fixing nematodes, clearing nematodes by slow and Seinhorst's methods;
- Preparation of temporary and permanent mounts;
- Measurements, drawing, microphotography, special preparation of nematodes – perineal patterns, vulval cones, en-face and body sections;
- Collection of root exudates, preparation of exhibits of nematode diseased plant material, in-vitro culturing techniques of nematodes- callous culture, excised root and carrot disc techniques.

VII. Suggested Reading

- Ayoub SM. 1981. Plant Nematology – An Agricultural Training Aid.
- Barker KR, Carter CC and Sasser JN. 1985. An Advanced Treatise on Meloidogyne. Vol. II.
- Methodology. International Meloidogyne Project, NCSU, Raleigh. USA.
- Manzanilla-Loìpez, RH and Marbaìn-Mendoza N. 2012. Practical Plant Nematology, Montecillo, TeXcoco: Biblioteca Basica de Agricultura.
- Sikora RA, Coyne D, Hallman J and Timper P. 2018. Plant Parasitic Nematodes in Subtropical and Tropical Agriculture.3rd edn. CABI Publishing, England.
- Southey JF. 1986. Laboratory Methods for Work with Plant and Soil Nematodes. HMSO, London.
- Subbotin SA, Mundo-Ocampo M and Baldwin J. 2010. Systematics of The Genus Heterodera in Systematics of Cyst Nematodes (Nematoda: Heteroderinae), Part B, Series: Nematology
- Monographs and Perspectives, Volume: 8B, Brill.
- Zuckerman BM, Mai WF and Harrison MB. 1985. Plant Nematology Laboratory Manual. Univ. of Massachusetts.

I. Course Title : Nematode Diseases of Crops

II. Course Code : NEMA 506

III. Credit Hours : 3(2+1)

IV. Aim of the course

To impart basic knowledge about the causal organism, nature of damage, symptoms

V. Theory

Diagnosis of causal organism, distribution, host range, biology and life cycle, nature of damage, symptoms, interaction with other organisms, and management of nematode diseases in different crops.

Unit I

Cereal crops- Ear-cockle and tundu diseases of wheat, molya disease of wheat and barley; rice root nematode, rice root-knot and cyst nematode problems, ufra and white tip diseases of rice; lesion nematodes, cyst nematodes of maize and sorghum.

Unit II

Pulses, Sugar, Fibre, Fodder and Oilseed crops- Pigeon pea cyst nematode, root knot nematode, reniform nematode, lesion, lance nematode, sugarbeet cyst and soybean cyst nematode problems.

Unit III

Vegetable crops- root-knot disease, reniform nematode, potato cyst nematode; stem and bulb nematode. Nematode problems of protected cultivation.

Unit IV

Fruit crops- root-knot nematode, reniform nematode, slow decline of citrus. Flowers- root-knot nematode, foliar nematodes, bulb nematodes, Mushroom- nematode problems.

Unit V

Plantation, medicinal and aromatic crops- burrowing nematode problem of banana, spices and condiments, root-knot and lesion nematode problems of coffee and tea, red ring disease of coconut. Forests- Pine wilt disease.

VI. Practical

- Diagnosis of causal organisms;
- Identification of different life cycle stages;
- Study of symptoms and histopathology of nematode damage in different crops, study tours for field diagnosis of nematode problems.

VII. Suggested Reading

- Bhatti DS and Walia RK. 1992. Nematode Pests of Crops. CBS, New Delhi.
- Bridge J and Starr JL. 2007. Plant Nematodes of Agricultural Importance: A Colour Handbook, CRC Press
- Evans AAF, Trudgill DL and Webster JM. 1994. Plant Parasitic Nematodes in Temperate Agriculture. CABI, Wallingford.
- Nickle WR. 1991. Manual of Agricultural Nematology. Marcel Dekker, New York. Perry RN and Moens M. 2006. Plant Nematology. CABI, Wallingford.
- Perry RN, Moens M and Jones JT. 2018. Cyst Nematodes, CABI Publishing: Wallingford, UK.
- Perry RN, Moens M and Starr JL. 2009. Root-knot nematodes, CABI Publishing: Wallingford,UK.
- Sikora R, Coyne D, Hallmann J and Timper P. 2018. Plant Parasitic Nematodes in Subtropical and Tropical Agriculture, 3rd Ed., CABI, UK.
- Walia RK and Khan MR. 2018. A Compendium of Nematode Diseases of Crop Plants, ICAR-AICRP (Nematodes), IARI, New Delhi.

I. Course Title : Nematode Biology and Physiology

II. Course Code : NEMA 507

III. Credit Hours : 3(2+1)

IV. Aim of the course

To develop understanding of life cycle patterns, feeding and metabolic processes in hytonematodes which have implications in their management.

V. Theory

Unit I

Host finding and invasion, feeding, hatching, moulting; life cycle patterns in different types of nematodes.

Unit II

Types of reproduction, gametogenesis, embryogenesis and post embryogenesis.

Unit III

Chemical composition of nematodes, hydrolytic enzymes, pseudocoelom and function of transport.

Unit IV

Physiology of digestive system, intermediary metabolism.

Unit V

Osmoregulation, physiology of excretory-secretory and neuromuscular systems.

VI. Practical

- Studies on embryogenesis and post-embryogenesis, hatching, moulting, life cycle development, feeding, enzymatic assay by electrophoresis.

VII. Suggested Reading

- Croll NA. 1970. The Behaviour of Nematodes: The Activity, Senses and Responses. Edward Arnold, London.
- Croll NA and Mathews BE. 1977. Biology of Nematodes. Blackie, Glasgow. Lee DL. 2002. The Biology of Nematodes. Taylor & Francis, London.
- Lee DL and Atkinson HJ. 1976. Physiology of Nematodes. MacMillan, London.
- Perry RN and Wright DJ. 1998. The Physiology and Biochemistry of Free- living and Plant Parasitic Nematodes. CABI, Wallingford.
- Wallace HR. 1963. The Biology of Plant Parasitic Nematodes. Edward Arnold, London.

I. Course Title : Nematode Ecology

II. Course Code : NEMA 508

III. Credit Hours : 3(2+1)

IV. Aim of the course

To understand the life of plant parasitic nematodes in their environment; their survival strategies, and how to exploit these for their control.

V. Theory

Unit I

Definition and scope; components of environment; evolution of nematodes; ecological classification, prevalence, distribution and dispersal of nematodes.

Role of nematodes in the food web; habitat and niche characteristics; community analysis and population estimation models.

Unit III

Effects of abiotic and biotic factors on nematodes.

Unit IV

Environmental extremes and nematode behaviour- aggregation, swarming, orientation, feeding and reproduction.

Unit V

Survival strategies of nematodes in adverse environment and absence of host.

Unit VI

Modeling population dynamics and relations with crop performance; ecological considerations in nematode management, data interpretation and systems simulation.

VI. Practical

- Study of nematode fauna in varied agro-ecological systems;
- Community analysis of nematode populations;
- Laboratory exercises on influence of abiotic factors on movement and hatching, green-house experiments on effect of abiotic factors on nematode populations and plant growth.

VII. Suggested Reading

- Croll NA. 1970. The Behaviour of Nematodes: The Activity, Senses and Responses. Edward Arnold, London.
- Croll NA and Mathews BE. 1977. Biology of Nematodes. Blackie, Glasgow. Lee DL. 2002. The Biology of Nematodes. Taylor & Francis, London.
- Gaugler R and Bilgrami AL. 2004. Nematode Behaviour, CABI, UK.
- Norton DC. 1978. Ecology of Plant Parasitic Nematodes. John Wiley. Poinar G. 1983. Natural History of Nematodes. Prentice Hall, Englewood Cliffs.
- Wallace HR. 1973. Nematode Ecology and Plant Disease. Edward Arnold, London.

I. Course Title : Nematode Interactions with Other Organisms

II. Course Code : NEMA 509

III. Credit Hours : 3(2+1)

IV. Aim of the course

To understand the role of nematodes in disease complexes involving fungal, bacterial, viral and other organisms.

V. Theory

Unit I

Concept of interaction and its importance in disease complexes and their management involving nematode and other organisms.

Unit II

Interaction of plant parasitic nematodes with wilt causing fungal pathogens and microfungi.

Unit III

Interaction of plant parasitic nematodes with root rot and other fungal pathogens.

Unit IV

Interaction of plant parasitic nematodes with bacterial pathogens, other nematode species and arthropods.

Unit V

Virus transmission by nematodes.

VI. Practical

- Green-house experiments to study the role of plant parasitic nematodes in wilt/ rot causing fungal and bacterial pathogens.

VII. Suggested Reading

- Khan MW. 1993. Nematode Interactions. Chapman & Hall, New York.
- Lamberti F, Taylor CE and Seinhorst JW. 1975. Nematode Vectors of Plant Viruses. Plenum Press, London.
- Mondia JL and Timper P. 2016. Interactions of microfungi and plant parasitic nematodes. In: Biology of Microfungi (De-Wei-Lei Ed.). Springer Publications
- Sasser JN and Jenkins WR. 1960. Nematology: Fundamentals and Recent Advances with Emphasis on Plant Parasitic and Soil Forms. Eurasia Publ. House, New Delhi.

I. **Course Title : Nematode Management**

II. **Course Code : NEMA 510**

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

IV. Aim of the course

To impart comprehensive knowledge about the principles and practices of nematode management.

V. Theory

Unit I

Concepts and history of nematode management; crop loss estimation, ecological and socio-economic aspects, cost-benefit ratios and pest risk analysis.

Unit II

Chemical methods- nematicides, their types, classification, mode of action, applicators and application methods, antidotes, and economizing nematicidal use.

Unit III

Cultural practices- crop rotations and cropping sequences, fallowing, flooding, soil solarisation, time of sowing, organic amendments of soil, bio-fumigation, antagonistic and trap crops, sanitation, etc. Physical methods- use of heat, hot water treatment and other methods of disinfestations of planting material.

Unit IV

Biological methods- concepts and terminology, use of predators and parasites as biological control agents, their mass multiplication and field use; phytotherapeutic methods – use of antagonistic plants and antinemic plant products.

Unit V

Genetic methods- plant resistance; legal methods- quarantine regulations; integrated Nematode management-concepts and management

VI. Practical

- In-vitro screening of synthetic chemicals and plant products for nematicidal activity, and their application methods;
- Methods for screening of crop germplasm for resistance against nematodes, laboratory eXercises on biocontrol potential of fungal, bacterial parasites, and predacious fungi and nematodes.

VII. Suggested Reading

- Bhatti DS and Walia RK. 1994. Nematode Pest Management in Crops. CBS, New Delhi. Brown GL. 1977. The Nematode Destroying Fungi. CBP, Guelph.
- Brown RH and Kerry BR. 1987. Principles and Practice of Nematode Control in Crops. Academic Press, Sydney.
- Chen ZX, Chen SY and Dickson DW. 2004. Nematology: Advances and Perspectives. Vol. II: Nematode Management and Utilization. CABI, Wallingford.
- Perry RN and Moens M. 2013. Plant Nematology. 2nd Ed., CABI, Wallingford, London.

- Starr JL, Cook R and Bridge J. 2002. Plant Resistance to Parasitic Nematodes. CABI, Wallingford. Stirling GR. 2014. Biological Control of Plant parasitic Nematodes, 2nd Ed., CAB International, UK.
- Whitehead AG. 1997. Plant Nematode Control. CABI, Wallingford.

I. Course Title : Beneficial Nematodes
II. Course Code : NEMA 511
III. Credit Hours : 2(1+1)
IV. Aim of the course

To sensitize about the use of nematodes for the biological control of insect pests of crops, and application of some nematodes as biological models and as indicators of environmental pollution.

V. Theory

Unit I

Beneficial nematode fauna – predators, parasites of insects, molluscs and other pests; Entomophilic nematodes- important groups, types of nematode- insect associations; taxonomic characteristics of nematode parasites of insects.

Unit II

Host-parasite relations and life cycle of mermithids, entaphelenchids, thelastomids, sphaerularids and tylenchids.

Unit III

Entomopathogenic nematodes- Steinernema, Heterorhabditis, Oscheius their morphological characteristics, taxonomic status, biology and mode of action.

Unit IV

Entomopathogenic nematodes- mass multiplication techniques, formulations, field applications and efficacy, success stories.

Unit V

Nematodes as biological models, nematodes as indicators of pollution, role of nematodes in organic matter recycling.

VI. Practical

- Isolation, identification, mass rearing and application methods of entomopathogenic nematodes.

VII. Suggested Reading

- Gaugler R and Kaya HK. 1990. Entomopathogenic Nematodes in Biological Control. CRC Press, Boca Raton, Florida.
- Gaugler R. 2002. Entomophilic Nematology. CABI, Wallingford. Grewal PS, Ehlars RU and Shapiro DI. 2005. Nematodes as Biocontrol Agents. CABI, Wallingford.
- Jairajpuri MS and Khan MS. 1982. Predatory Nematodes (Mononchida). Associated Publ. Co., New Delhi.
- Wood WB. 1998. The Nematode Caenorhabditis elegans. Cold Spring Harbor Press.

- Woodring JL and Kaya HK. 1988. Steinernematid and Heterorhabditid Nematodes: A Handbook of Techniques. Southern Coop. Bull., Ark. Ag. Ext. Sta.
- Zuckerman BM. (Ed.). 1980. Nematodes as Biological Models. Vols. I, II. Academic Press, New York.

I. Course Title : Principles of Integrated Pest Management

II. Course Code : NEMA 512

III. Credit Hours : 2(1+1)

IV. Aim of the course

To familiarize the students with principles of insect pest management, including concept and philosophy of IPM. Train students in computation of ETL, implementing IPM programmes.

V. Theory

Unit I

History and origin, definition and evolution of various related terminologies.

Unit II

Concept and philosophy, ecological principles, economic threshold concept, and economic consideration.

Unit III

Tools of pest management and their integration- legislative, cultural, physical and mechanical methods; pest survey and surveillance, forecasting, types of surveys including remote sensing methods, factors affecting surveys; political, social and legal implications of IPM; pest risk analysis; pesticide risk analysis; cost-benefit ratios and partial budgeting; case studies of successful IPM programmes.

VI. Practical

- Characterization of agro-ecosystems;
- Sampling methods and factors affecting sampling;
- Population estimation methods;
- Crop loss assessment- direct losses, indirect losses, potential losses, avoidable losses, unavoidable losses;
- Computation of EIL and ETL;
- Crop modeling; designing and implementing IPM system.

VII. Suggested Reading

- Dhaliwal GS and Arora R. 2003. Integrated Pest Management – Concepts and Approaches.
- Kalyani Publishers, New Delhi.
- Dhaliwal GS, Ram Singh and Chhillar BS. 2006. Essentials of Agricultural Entomology. Kalyani Publishers, New Delhi. Flint MC and Bosch RV. 1981. Introduction to Integrated Pest Management. 1st Ed., Springer, New York.
- Horowitz AR and Ishaaya I. 2004. Insect Pest Management: Field and Protected Crops. Springer, New Delhi.
- Ignacimuthu SS and Jayaraj S. 2007. Biotechnology and Insect Pest Management. Elite Publ., New Delhi.

- Metcalf RL and Luckman WH. 1982. Introduction of Insect Pest Management. John Wiley & Sons, New York.
- Norris RF, Caswell-Chen EP and Kogan M. 2002. Concepts in Integrated Pest Management. Prentice Hall, New Delhi.
- Pedigo RL. 2002. Entomology and Pest Management. 4th Ed. Prentice Hall, New Delhi.
- Subramanyam B and Hagstrum DW. 1995. Integrated Management of Insects in Stored Products. Marcel Dekker, New York.

I. Course Title : Disease Resistance in Plants

II. Course Code : NEMA 513

IV. Aim of the course

To acquaint with disease resistance mechanisms in plants.

V. Theory

Unit I

Introduction and historical development, dynamics of pathogenicity, process of infection, variability in plant pathogens, gene centres as sources of resistance, disease resistance terminology.

Unit II

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

Unit III

Host defence system, morphological and anatomical resistance, preformed chemicalsin host defence, post infectional chemicals in host defence, hypersensitivity and its mechanisms.

Unit IV

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

VI. Suggested Reading

- Dallice M et al.1996. Molecular Aspects of Pathogenicity and Resistance: Requirement for Signal Transduction. APS, St Paul, Minnesota.
- Deverall, B.J. 1977. Defence Mechanisms in Plants. Cambridge Univ. Press, Cambridge, New York.
- Parker J. 2008. Molecular Aspects of Plant Diseases Resistance. Blackwell Publ.
- Robinson RA. 1976. Plant Pathosystems. Springer Verlag, New York. Singh BD. 2005. Plant Breeding – Principles and Methods. 7th Ed. Kalyani Publishers, Ludhiana.
- Van der Plank JE. 1975. Principles of Plant Infection. Academic Press, New York.
- Van der Plank JE. 1978. Genetic and Molecular Basis of Plant Pathogenesis. Springer Verlag, New York.
- Van der Plank JE. 1984. Disease Resistance in Plants. Academic Press, New York.

I. Course Title : Plant Quarantine, Biosafety and Biosecurity
II. Course Code : NEM 514
III. Credit Hours : 2(2+0)
IV. Aim of the course

To acquaint the learners about the principles and the role of Plant Quarantine in containment of pests and diseases, plant quarantine regulations and set-up.

V. Theory

Unit I

Definition of pest, pesticides and transgenics as per Govt. notification; relative importance; quarantine – domestic and international. Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case histories of exotic pests/ diseases and their status.

Unit II

Plant protection organization in India. Acts related to registration of pesticides and transgenics. History of quarantine legislations, PQ Order 2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

Unit III

Identification of pest/ disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniques to detect pest/ pathogen infestations; VHT and other safer techniques of disinfestation/ salvaging of infected material.

Unit IV

WTO regulations; non-tariff barriers; Pest risk analysis, good laboratory practices for pesticide laboratories; pesticide industry; Sanitary and Phytosanitary measures.

VI. Suggested Reading

- Rajeev K and Mukherjee RC. 1996. Role of Plant Quarantine in IPM. Aditya Books.
- Rhower GG. 1991. Regulatory Plant Pest Management. In: Handbook of Pest Management in Agriculture. 2nd Ed. Vol. II. (Ed. David Pimental). CRC Press.
- Shukla A and Veda OP. 2007. Introduction to Plant Quarantine. Samay Prakashan, New Delhi.

I. Course Title : IPM in Protected Cultivation
II. Course Code : NEMA 515
III. Credit Hours : 3(2+1)
IV. Aim of the course

To sensitize the pest and disease scenario developing in crops raised under protected cultivation and to impart knowledge about the remedy.

V. Theory

Unit I

Characteristics of protected cultivation and tools for sustainable crop production; outline of major biotic stresses in protected cultivation including: fungi, bacteria, virus, nematode, insects and mites.

Unit II

Sampling and monitoring pests and diseases; epidemiology and damage relationships; loss assessment; population dynamics of biotic stress agents; factors responsible for severity of pests and diseases.

Unit III

Host plant resistance to pathogens and insects; management strategies for protected cultivation: disinfestation of soil and growth media; preventive, scouting and early detection; and curative measures: biological control of sap sucking pests, leaf miners; soil- and air-borne pathogens; pesticides selectivity, applications and resistance management; buzz pollination.

VI. Practical

- Visit to familiarize with pest and disease situations developing in protected cultivation;
- Symptomatology and damages; identification of the causes; estimation of population densities; management tactics/ approaches and recommendations; production and commercialization of biological agents.

VII. Learning outcome

Students are eXpected to be well versed with the crop pest and disease problems associated with protected cultivation and their management.

VIII. Suggested Reading

- Gullino ML, Albajes, R and Nicot P. 2019. Integrated Pest and Disease Management in Greenhouse Crops. Ed. 2nd, Springer, New York.
- Rathee et al. 2018. Integrated Pest Management under Protected Cultivation—A Review. Journal of Entomology and Zoology Studies, 6 (2): 1201–1208.

IX. List of Journals

- Annals of Applied Nematology – Society of Nematologists, USA
- Current Nematology – Bioved Research Society, Allahabad, India
- Egyptian Journal of Agronematology – Egyptian Society of Agricultural Nematology
- Indian Journal of Nematology – Nematological Society of India
- International Journal of Nematology – Afro-Asian Society of Nematologists, Luton
- Japanese Journal of Nematology – Japanese Nematological Society
- Journal of Nematology – Society of Nematologists, USA
- Journal of Nematode Morphology and Systematics –Jaen, Universidad de Jaen
- Nematologia Brasiliera – Brazilian Nematological Society
- Nematologia Mediterranea – Istituto per la Protezione delle Plante (IPP) – Sect. of Bari of the CNR, Italy
- Nematology – EJ Brill Academic Publishers, UK

- Nematropica – Organization of Nematologists of Tropical America
- Pakistan Journal of Nematology – Pakistan Society of Nematologists
- Russian Journal of Nematology – Russian Society of Nematologists

e-Resources

http://www.nematologists.org/ (The Society of Nematologists)
http://nematology.ucdavis.edu/ (Deptt. of Nematology, Univ. of California, Davis)
http://www.ifns.org/ (International Federation of Nematology Societies)
http://www.inaav.ba.cnr.it/nemmed.html (Nematologia Mediterranea)
http://nematode.unl.edu/Nemajob.htm (Nematology Employment Bulletin Board)
http://nematode.unl.edu/ (University of Nebraska – Lincoln Nematology)
http://nematode.unl.edu/wormsite.htm (Links to Other Nematology Resources)
http://nematode.unl.edu/SON/jon.htm (Journal of Nematology)
http://www.nematology.ucr.edu/ (Deptt. of Nematology, Univ. of California, Riverside)
http://entnemdept.ifas.ufl.edu/ (Univ. of Florida, Entomology and Nematology Dept.)
http://www.brill.nl/m_catalogue_sub6_id8548.htm (Nematology – journal)
http://www.ars.usda.gov/main/site_main.htm?modecode=12752900 (Nematology Lab., USDA)
http://flnem.ifas.ufl.edu/history/nem_history.htm (Nematology history)
http://www.nematology.ugent.be/ (Nematology Unit, Ghent University)
http://www.entm.purdue.edu/nematology/ (The Purdue Nematology Lab.)
http://www.bspp.org.uk/ppigb/nematolo.htm#a-z (Links to Nematology labs)
http://www.nem.wur.nl/UK/ (Laboratory of Nematology, Wageningen Univ.)
http://onta.ifas.ufl.edu/ (The Organization of Nematologists of Tropical America)
http://www.openj-gate.org/Articlelist.asp?Source=1&Journal_ID=103267. (Nematology Newsletter)
http://nematology.umd.edu/nematology.html (Plant Nematology Laboratory, Maryland)
http://www.biology.leeds.ac.uk/nem/ (Plant Nematology Lab., University of Leeds)
http://www.plantpath.iastate.edu/dept/labs/tylka/ (Iowa State University, Nematology Lab)
http://nematologists.org.au/newsletters.html (Australasian Association of Nematologists)
http://soilplantlab.missouri.edu/nematode/ (Plant Nematology Laboratory, Missouri)
http://www.eumaine.ugent.be/ (European Master of Science in Nematology)
http://www.jstage.jst.go.jp/browse/jjn (The Japanese Journal of Nematology)

Suggested Broad Topics for Master's and Doctoral Research

- Identification of key nematode pests emerging in regional agro-ecosystems
- Development of molecular diagnostic tools of phytonematodes
- Nematode problems of peri-urban and protected agriculture systems, and their management
- Role of nematodes in organic matter recycling
- Modelling nematode populations for disease forecasting and predicting yield losses
- Nematodes as indicators of environmental pollution
- Identification of cost effective nematode-suppressive cropping systems for specific agro- ecosystems
- Isolation, identification and characterization of phytochemicals for nematoxicity
- Disinfection of nematode-infected planting material through eco-friendly sanitary methods

- Characterization of molecular markers and genes governing resistance to key nematode pests
- Management of nematodes with antagonistic bacteria
- Bionomics of potential bio-control agents and their field efficacy
- Devising non-chemical methods of nematode management in mushroom cultivation
- Development of nematode management modules for IPM systems
- Field efficacy and formulation of entomopathogenic nematodes against foliar and soil-borne insect pests of crops
- Study of disease complex involving nematodes and other plant pathogens.
- Nematode suppressive rhizospheric microorganisms.
- Nematode suppressive endophytes.
- Management of nematodes using RNAi
- Factors related to entomopathogenic nematode- bacterium symbionts
- Management of root knot nematodes in protected cultivation system
- Assessment of nematode damage and yield losses in organic farming system

PLANT PHYSIOLOGY

Course Title with Credit Load

M.Sc (Agri) Plant Physiology

Course Code	Course Title	Credit Hours
PP 501	Principles of Plant Physiology-I: Plant Water Relations	3(2+1)
	and Mineral Nutrition	
PP 502	Principles of Plant Physiology-II: Metabolic Processes	3(2+1)
	and Growth Regulation	
PP 503	Plant Developmental Biology: Physiological and	3(2+1)
	Molecular Basis	
PP 504	Physiological and Molecular Responses of Plants to	3(2+1)
	Abiotic Stresses	
PP 505	Hormonal Regulation of Plant Growth and Development	3(2+1)
PP 506	Physiological and Molecular Mechanisms of Mineral	3(2+1)
	Nutrient Acquisition and their Functions	
PP 507	Photosynthetic Processes, Crop Growth and Productivity	3(2+1)
	and Concepts of Crop Modelling	
PP 508	Physiology of Field Crops	2(2+0)
PP 509	Physiology of Horticulture Crops	2(2+0)
PP 510	Seed Physiology	3(2+1)
PP 511	Phenotyping Physiological Processes	2(2+0)
PP 512	Crop Growth Regulation and Management	2(2+0)

Course Contents
M.Sc (Agri) Plant Physiology

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

II. Course Code : PP 501*

III. Credit Hours : 3(2+1)

IV. Why this Course?

Plant's growth and development and therefore, agricultural productivity depends on two major inputs like water and nutrients. In this regard, this course being a fundamental course will acquaint the students with the basic concepts of plant water relations and mineral nutrition. The course provides a basic knowledge on water and nutrient acquisition and their transport throughout the phenological stages. Further, it also provides hands on eXperience in assessing the plant and soil water status besides nutrient acquisition by plants.

V. Aim of the Course

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:

No.	Blocks	Units
1.	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
2.	Mineral Nutrition	1. Nutrient Elements and their Importance
		2. Nutrient Acquisition
		3. Concept of Foliar Nutrition

VI. Theory

Block 1: Plant Water Relations

Unit 1: 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 2: 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 3: 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 4: 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 5: 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 2: Mineral Nutrition

Unit 1: 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 2: 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 3: 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.

VII. Practicals

- 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

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

- comprehend the fundamental concepts of plant physiological processes associated with water relation and mineral nutrition.
- describe the physiological mechanisms of water relation and mineral nutrition.
- recognize and describe how plants respond to mineral deficiency and toxicity.

X. Suggested Reading

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General Source of Information

- Taiz T, Zeiger E and Max Mller IM, 2018, Fundamentals of Plant Physiology
- Taiz L and Zeiger E. 2015. Plant Physiology and development.6th Ed
- Salisbury FB and Ross C. 1992 (4th Ed.) Plant Physiology
- Epstein E and Bloom AJ. 2004. Mineral nutrition of plants: principles and perspectives.2nd Ed.
- Hopkins WG and Huner NPA. 2004. Introduction to Plant Physiology
- Kramer, P. J., Water relations of plants
- Kirkham, M. B., Principles of soil and plant water relations
- Hopkins WG, 2008, Introduction to Plant Physiology

I. Course Title : Principles of Plant Physiology-II: Metabolic Processes and Growth Regulation

II. Course Code : PP 502

III. Credit Hours : 3(2+1)

IV. Why this course?

Mechanisms associated with growth and development determine crop performance under any given condition. Metabolic and growth processes are quite sensitive to environmental factors and hence comprehensive understanding of the physiological basis of growth and development would be essential.

V. Aim of the course

This course will impart knowledge on cellular structure and function that determine of carbon and nitrogen metabolism, lipids, enzymes and secondary metabolites in plants. Relevance of metabolic processes on growth and development leading to productivity will be dealt.

The course is organized as follows:

No.	Blocks	Units
1.	Metabolic processes and growth regulation	1. Carbon Metabolism–Photochemical Processes
		2. Carbon Metabolism: Biochemical Processes
		3. Carbon Metabolism: Respiration
		4. Product Synthesis and Translocation Leading to Crop Growth

5. Nitrogen Assimilation and Protein Synthesis
6. Lipid Metabolism and Secondary Metabolites
7. Hormonal Regulation of Plant Growth and Development
8. Synthetic Growth Promoters
9. Morphogenesis and Reproductive Phase

VII. Theory

Block 1: Metabolic Processes and Growth Regulation

Unit 1: Carbon Metabolism – Photochemical Processes

- Chloroplast ultrastructure with special mention of lamellar system
- Excitation, electron and proton transfers and their relevance in energy conservation
- Concepts of pigment systems and generation of powerful reductant and oxidant
- Water oxidation, Water-water cycle and other aspects of electron transfer

Unit 2: Carbon Metabolism: Biochemical Processes

- CO_2 diffusion mechanisms and diffusive conductances, concept of Ci determining Photosynthesis
- RuBisCO enzyme kinetics and Calvin cycle mechanisms, Regulation of Calvin cycle and metabo lite fluxes
- Photorespiration: the advantages and inefficiencies of photosynthesis because of photorespiration
- Concepts of CO_2 concentrating mechanisms (CCM) and spatial and temporal differences in carboxylation
- Ecological aspects of $C_4$and CAM photosynthesis
- Product synthesis, Starch and Sucrose biosynthesis

Unit 3: Carbon Metabolism: Respiration

- Mitochondrial organization and functions
- Aspects of Glycolysis, TCA cycle and mitETC.
- Relevance of growth and maintenance respiration
- Concepts of CN resistance respiration – Alternate and SHAM sensitive ETC

Unit 4: Product Synthesis and Translocation Leading to Crop Growth

- Phloem loading and sugar transporting, concepts of bi-directional transport of sugars and other metabolites
- Source-Sink relationship and modulation of photosynthesis
- Concepts and definitions of Growth and Differentiation
- Growth and yield parameters, NAR, CGR, HI and concepts of LAI, LAD

Unit 5: Nitrogen Assimilation and Protein Synthesis

- Developments in d-nitrgen fixation
- Nitrate reduction and assimilation GS-GOGAT process for amino acid synthesis
- Inter-Dependence of carbon assimilation and nitrogen metabolisms

Unit 6: Lipid Metabolism and Secondary Metabolites

- Storage, protective and structural lipids.
- Biosynthesis of fatty-acids, diacyl and triacyl glycerol, fatty acids of storage lipids.
- Secondary metabolites and their significance in plant defense mechanisms.

Unit 7: Hormonal Regulation of Plant Growth and Development

- Growth promoting and retarding hormones: biosynthesis, transport, conjugation
- Mode of action of these hormones and their application in plant physiology

Unit 8: Synthetic Growth Promoters

- Different synthetic hormones: Salicylic acid, strigolactones etc
- Roles and biological activities of various synthetic hormones
- Commercial application of hormones to maximize growth and productivity

Unit 9: Morphogenesis and Reproductive Phase

- Photoperiodism: Phytochromes, their structure and function
- Circadian rhythms,
- Blue light receptors: Cryptochrome and morphogenesis.
- Vernalization and its relevance in germination.

VII. Practicals

- Radiant energy measurements
- Separation and quantification of chlorophylls
- Separation and quantification of carotenoids
- O_2 evolution during photosynthesis
- Anatomical identification of C_3 and C_4 plants
- Measurement of gas exchange parameters, conductance, photosynthetic rate, photorespiration
- Measurement of respiration rates
- Estimation of reducing sugars, starch
- Estimation of NO_3, free amino acids in the xylem exudates, quantification of soluble proteins
- Bioassays for different growth hormones- Auxins, Gibberellins, Cytokinins, ABA and ethylene
- Demonstration of photoperiodic response of plants in terms of flowering

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

– figure out the fundamental metabolic processes in plant
– describe the physiological mechanisms and metabolic events associated with regulation of plant growth

X. Suggested Reading

- Kirchhoff H. 2019. Chloroplast ultrastructure in plants, New Phytologist. Doi.org/10.1111/nph.15730
- Jafari T, Moharreri E, Amin A, Miao R, Song W and Suib S. 2016. Photocatalytic water splitting—the untamed dream: a review of recent advances. Molecules, 21(7), 900.
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- Kühlbrandt W. 2015. Structure and function of mitochondrial membrane protein complexes. BMC biology, 13(1), 89.
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- Eckardt, N. A. 2015. The plant cell reviews dynamic aspects of plant hormone signaling and crosstalk.
- Jiang, K., andAsami, T. 2018. Chemical regulators of plant hormones and their applications in basic research and agriculture. Bioscience, biotechnology, and biochemistry, 82(8), 1265- 1300.
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- Kumar, R., Khurana, A., and Sharma, A. K. 2014. Role of plant hormones and their interplay in development and ripening of fleshy fruits. Journal of experimental botany, 65(16), 4561- 4575.
- Gururani, M., Mohanta, T., and Bae, H. 2015. Current understanding of the interplay between

phytohormones and photosynthesis under environmental stress. International journal of molecular sciences, 16(8), 19055-19085.

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- Taiz, Lincoln, Zeiger. 2007 Plant Physiology, Eduardo Original American edition Sinauer Asso ciates, Inc., 2006; 4th ed., XXVI, ISBN: 978-3-8274-1865-4; © Springer.
- Plant Physiology Frank Boyer Salisbury and Cleon Ross.
- Introduction to Plant Physiology (Wie)by William G. Hopkins.

I. Course Title : Plant Developmental Biology: Physiological and Molecular Basis

II. Course Code : PP 503

III. Credit Hours : 3(2+1)

IV. Why this Course?

From the conventional description information on plant growth and development based on morphology and anatomy, phenomenal changes and leads taken place in the last one and half decade to address these processes at physiological, biochemicaland molecular levels. This basic understanding has provided options to regulate these processes genetically using genetic and molecular tools and by interventions using chemicals and external factors. To give an example on flowering, the progress made regarding the molecular players that regulate flowering, initiation, the photoreceptors like phytochromes and their regulation by the photoperiod-short and long days has provided options to manipulate the flowering time to bring in synchrony, etc. Phenomenal progress also made in several other processes like germination, viability, root development and pollination, etc. The other major area of contribution is in tissue culture where is understanding of plant developmental biology has been put o practical use and knowledge on morphogenesis is exploited to maximum. It is very essential that the students get exposed on these aspects to complement the research programs on crop improvement.

V. Aim of the course

To explain about basic physiological and molecular processes concerning various facets of growth and development of plants. It provides knowledge on basic physiological processes governing developmental events in plants including senescence and fruit development and ripening. Development of vegetative tissue like shoot, leaf and root and morphogenetic phenomena like flower induction and development, factors associated with photoperiod and thermoperiod response. Regulation of morphogenesis would be studied at the molecular level providing information on genes involved. In addition, students will study how to apply the knowledge on plant development and morphogenesis using tissue culture.

The course is organized as follows :

No.	Blocks	Units
1.	Plant Developmental Biology	1. Evolutionary Development of Plants and Role of Environment
		2. Physiological and Molecular Determinants of Seed Biology

		3.	Vegetative Growth and Organ Development
		4.	Physiological and Molecular Aspects of Reproduc tive Growth and Development
		5.	Ripening and Senescence
		6.	Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature
2.	Practical application of	1.	Tissue culture and micro-propagation morphogenesis
		2.	Application of in-vitro techniques for crop improvement

VI. Theory

Block 1: Plant Developmental Biology

Unit 1: Evolutionary Development of Plants and Role of Environment

Plant development and plasticity, evolution, Biodiversity. Novel features of plant growth and development, Concept of plasticity-evolution and biodiversity, Model plants for study; Environment and development. Developmental stages and program; Cell-cycle, totipotency and regeneration.Unit 2: Physiological and Molecular Determinants of Seed Biology Seed development- Physiology of seed development, role of hormones in embryo development; seed development and maturation. Seed dormancy-Physiological and molecular mechanism of seed dormancy regulation. Seed germination- seed structure and Hormonal regulation of germination, Mobilization of food reserves during seed germination.

Unit 3: Vegetative Growth and Organ Development

Regeneration and totipotency- organ differentiation and development – role of hormones- developmental control genes in crop plants. Meristems in plant development. Shoot, Leaf, Trichome and stomate development and differentiation. Axillary shoot branching; Bud dormancy and growth. Root development; Nodule development; Tuber development- hormonal control, signaling and molecularregulation-genes involved. Vascular bundle development- xylem and phloem differentiation

Unit 4: Physiological and Molecular Aspects of Reproductive Growth and Development

Floral Induction and Development: Molecular and physiological mechanism of transition -vegetative to reproductive phase- floral organ initiation and development their controls. Development of male and female gametophyte; gametophytic mutants: pollen-stigma interaction- Pollen germination and tube growth; role of imprinting; Male sterility: and fertility restoration; Self incompatibility; Sterility and fertility restoration, Maternal gene effects, Zygotic gene effects. Sex determination in plants, mate choice in plants. Embryo and endosperm development- fertilization, role of imprinting; Parthenocarpy and apomixes

Unit 5: Ripening and Senescence

Fruit development, enlargement, maturation and ripening; climacteric and non- climacteric fruit ripening mechanism. Hormonal, biochemical & Molecular aspects of fruit ripening. Senescence and its regulation; Hormonal and environmental control of senescence; PCD in the life cycle of plants.

Unit 6: Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature

Light control of plant development: Phytochromes and cryptochromes, phototropins, their structure, biochemical properties and cellular distribution. Molecular mechanisms of light perception, signal transduction and gene regulation. Photoperiodism and its significance, vernalization and hormonal control. Circadian rhythms-biological clocks and their genetic and molecular determinants. Thermomorphogenesis-Thermoperiodism

Block 2: Application of Morphogenesis and its Practical Application

Unit 1: Tissue culture and micro-propagation

Applications of tissue culture for plant production, callus induction, somatic embryogenesis, re-generation from different explants. Micro-propogation, tip and axillary node culture of commercially im-portant crops, hardening and ex-vitro establishment, concept of somatic hybridization and protoplast culture.

Unit 2: Application of in-vitro techniques for crop improvement

Development of somoclones, identification and exploitation of somoclonal variants. Haploid pro-duction, pollen/anther, ovule/ovary culture. Production of secondary metabolites by tissue culture, concept of bio-fermenters. Plant transformation, development of transgenic plants and their characterization. Germplasm storage, cryopreservation and regulation

VII. Practicals

- Studying shoot apical meristem, floral meristem development and pollen tube development
- Phenotyping photomorphogenesis: (a) Studying effect of day length (short day and long day) in regulating floral induction/ flowering time in short day/long day/day neutral plants and (b) effect of light on seed germination in light-sensitive and - insensitive seeds.
- Studying effect of temperature on– (a) thermomorphogenesis- measuring hypocotyl elongation under different temperature conditions and (b) sex determination using cucurbits/sesame plants.
- Measure physiological paramters of fruit ripening and study the expression of key genes regulating ripening.
- Study the effect of ethylene, its inhbibitor and scruber on ripening (tomato).
- Study different sterilization techniques, prepare media stocks and plant hormones.
- Inoculate explant (seed and leaf tissue) of model plant for callus induction.
- Subculture the callus and standerdize regeneration protocol for shoot and root induction using callus and leaf explant.
- Micro-propagation using meristem tip and axillary node culture.
- Standerdize anther/ pollen culture for haploid production in model/crop/horticultural plant.
- Isolation of protoplast from Arabidopsis/tobacco and its culturing
- Study about selectable marker, reporter gene, PCR, southern and northern blotting techniques.
- Transformation of tobacco callus or leaf explant by Agrobacterium tumefacines and Agrobacterium rhizogenes for production of transgenic
- Molecular characterization of transgenic- PCR, southern blotting, gene expression.

VIII. Teaching methods/activities

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

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular basis of plant growth and development. The student will develop critical insight in physiological aspects of vegetative growth and reproductive development at molecular level.

X. Suggested Reading

- Niklas KJ. Plant Evolution- An Introduction to the History of Life.
- Bahadur B et al. (eds.), Plant Biology and Biotechnology: Volume I: Plant Diversity, Organization, Function and Improvement
- Jong MD and Leyser O. Developmental Plasticity in Plants. Cold Spring Harbor Symposia on Quantitative Biology. 63-73.
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- Franklin KA and Wigge PA. Temperature and Plant Development. Wiley Blackwell.
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- Bhojwani SS and Razdan MK. Plant tissue culture: theory and practice, a revised edition. Elsiver publication.
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- George EF and Hall MA. Plant Propagation by Tissue Culture 3rd Edition.
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General Source Information

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I. Course Title : Physiological and Molecular Responses of Plants to Abiotic Stresses

II. Course Code : PP 504

III. Credit Hours : 3(2+1)

IV. Why this course?

With the changing climate, plants are being more frequently exposed to abiotic stresses like, water, salinity, temperature, nutrient, radiation, etc. limiting the productivity. This will not only affect livelihoods of individual farmers but also the food security. Concerted efforts have been made to grow crops under resource limited/stressful environmental conditions and advances in physiology, molecularbiology and genetics have significantly helped in this endeavor. In recent years, our understanding of the physio-morphological, biochemical and molecular adaptation of plants to resource limited/stressful environment is phenomenal. This course will outline different abiotic stresses, their impacts on agricultural productivity, stress tolerance mechanisms, stress mitigation strategies, crop improvement approaches and traits for stress tolerance.

V. Aim of the course

This course aims to describe students the abiotic-stress physiology and their effects on plant growth and productivity. This will also help students gain insights into latest developments in stress physiology and stress tolerance mechanisms, approaches for crop improvement under stressful environment.

The course is organized as follows:

No.	Blocks	Units
1.	Abiotic Stresses	1. Introduction to Abiotic Stresses
2.	Drought Stress	1. Moisture Stress Responses in Plants
		2. Stress Perception and Molecular Responses of Plants to Drought Stress
		3. Plant Adaptive Mechanisms to Drought
		4. Approaches to Improve Drought Tolerance
3.	Salt, Heavy Metal, Water Logging, Temperature and Light Stress	1. Salt Stress
		2. Heavy Metal Stress and Water Logging
		3. Temperature and Light Stress

VI. Theory

Block 1: Abiotic Stresses

Unit 1: Introduction to Abiotic Stresses

Abiotic stresses major constraints to realize potential yields of crop plants, yield losses. Drought prone areas in India- Frequency of occurrence of drought, Rainfed- kharif, Rabi, Areas affected by salinity, heavy metals, water logging, high temperature scenario due to global warming.

Block 2: Drought Stress

Unit 1: Moisture Stress Responses in Plants

Drought-characteristic features; water potential in the soil-plant-air continuum. Physiological and biochemical processes affected by drought.Oxidative stress- generation of ROS and other cytotoxic compounds, their effect on cellular process. Effect on total carbon gain- decrease in photosynthetic area and function, protein turn over and lipid characters, phenology-reproductive aspects, critical stages.

Unit 2: Stress Perception and Molecular Responses of Plants to Drought Stress

Stress perception andsignal transduction leading to expression of regulatory genes, stress specific kinases, stress specific transcription factors, functional genes associated with adaptive mechanisms.

Unit 3: Plant Adaptive Mechanisms to Drought

(a) Escape and desiccation avoidance mechanismConcept of stress escape-exploiting genetic variability in phenology, Drought avoidance mechanisms- Maintenance of cell turgor, water mining by root characters. Moisture conservation- Regulation of transpiration- traits reducing heat load, Stomatalfactors guard cell metabolism, moisture conservation by waxes. Water use efficiency (WUE) and concept of water productivity- regulation of transpiration efficiency-stomatal conductance, mesophyll efficiency, relevance of WUE and Passioura's model.

(b) Desiccation tolerance- Concept of acquired tolerance Decreased turgor mediated upregulation of cellular tolerance mechanisms, Osmolytes, managing cytotoxic compounds, ROS, RCC, scavenging - enzymatic and non-enzymatic, protein turnover, stability, chaperones, membrane stability, photo- protection of chlorophylls.

Unit 4: Approaches to Improve Drought Tolerance

Development of genetic resources- donor genotypes for specific traits, Genomic resources- genes, QTL's regulating adaptive mechanisms, Conventional, transgenic and molecular breeding approaches to improve relevant adaptive traits, concept of trait introgression.

Block 3: Salt, Heavy Metal, Water Logging, Temperature and Light Stress

Unit 1: Salt Stress

Soil salinity-Effect of salt stress, ionic and osmotic effects; species variation in salt tolerance; glycophytes and halophytes, Salt tolerance mechanisms - exclusion, extrusion and compartmentalization, Signaling during salt stress – SOS pathway, Approaches to improve salt tolerance.

Unit 2: Heavy Metal Stress and Water Logging

Heavy metal toxicity in plants (eg., Al, Cd), tolerance mechanisms and approaches to improve. Plant response to water logging, role of hormones- ethylene, mechanism of tolerance and approaches to improve.

Unit 3: Temperature and Light Stress

High and low temperatures; effect on plants; adaptive mechanisms, evaporation cooling, concept of cellular tolerance, protein stability, chaperones, HSPs, HSFs, membranes. High light and high ionizing radiation- photo oxidation and photo- inhibition; mechanisms of tolerance, plant adaptation to low light, concept of shade avoidance response (SAR).

VII. Practicals

- Measurement of soil and plant water status.
- Drought stress imposition and measurement of physiological and biochemical changes in plants under stress –gas exchange and fluorescence measurements.
- Determination of water use efficiency as a drought resistant trait.
- Drought Susceptibility Index (DSI) -precise field technique to identify productive genotypes under stress.
- Approaches to quantify root characters
- Determination of stomatal parameters and canopy temperature as a reflection of transpiration and root activity.
- Determination of Salinity Tolerance Index.
- Studying acclimation response - Temperature induction response.
- Heat tolerance and membrane integrity- Sullivans heat tolerance test.
- Quantification of osmolytes – proline under stress.
- Oxidative stress imposition- Quantification of oxidative stress
- Quantification of ROS under stress.
- Estimation of ABA content in leaf and root tissues under stress.
- Determination of Sodium and Potassium in plant tissue grown under salt stress.
- Estimation of antioxidant enzymes.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular responses of plants to abiotic stresses. The student will develop critical insight in adaptive mechanisms of plants against various abiotic stresses.

X. Suggested Reading

- Plant Physiology Book by Eduardo Zeiger and Lincoln Taiz.
- Plant Physiology Book by Frank B. Salisbury, Cleon W. Ross Salisbury, Frank B
- Pereira A. 2016. Plant Abiotic Stress Challenges from the Changing Environment. Front. Plant Sci. 7: 1123. doi: 10.3389/fpls.2016.01123
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- Lata C and Muthamilarasan M and Prasad M. 2015. Drought Stress Responses and Signal Transduction in Plants. In elucidation of abiotic stress signaling in plants (PP.195-225). Springer, New York,Ny. DOI: 10.1007/978-1-4939-2540-7_7.
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I. Course Title : Hormonal Regulation of Plant Growth and Development

II. Course Code : PP 505

III. Credit Hours : 3(2+1)

IV. Why this Course?

Many plant growth and developmental processes are regulated by phytohormones.It is important to understand the hormone biosynthesis, structure, function, signal transduction and their practical application. It is also important to provide basic knowledge on manipulating growth and developmental processes using plant hormones.

V. Aim of the course

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:

No.	Blocks	Units
1.	Plant Growth and Development: Hormonal Regulation	1. Introduction to Plant Hormones 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

VI. Theory

Block 1: Plant Growth and Development: Hormonal Regulation Unit 1: 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 2: 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 3: 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 inelucidating 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 Brassinosteroidsand 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 4: 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 Tricontanol, 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 Tricontanol at physiological and molecular level.

Unit 5: 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 6: Key Genes Regulating Hormone Levels and Functions

Genomics approaches to regulate hormone metabolism and its effect on plant growth and development – case studies.

Unit 7: 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 8: 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 gynoecious 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.

VII. Practicals

- 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

VIII. Teaching methods/activities

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

IX. Learning outcome

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

- acquire basic knowledge about plant hormones and plant growth regulators.
- understand the physiological roles and mechanisms of actions of plant hormone.
- obtain practical knowledge about application of plant growth regulators in agricultural and horticulture.

X. 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.
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- 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/)

I. Course Title : Physiological and Molecular Mechanisms of Mineral Nutrient Acquisition and their Functions

II. Course Code : PP 506

III. Credit Hours : 3(2+1)

IV. Why this course?

In both basic and applied plant sciences, an understanding of the mineral nutrition of plants is of fundamental importance. Nutrient element forms the skeleton of any organic molecule in the organism vis-à-vis plant. Apart from the conventional information on criteria of essentiality, nutrient uptake pathways, function of essential elements and their deficiency and toxicity symptoms, remarkable advances have been made at physiological and molecular level. Exploration of the physiological mechanisms adopted by plants to tolerate the deficiency of specific nutrient elementprovides an opportunity alter the plants' ability to cope with the low nutrient condition. Identification and functional validation of various transporters involved in nutrient uptake and distribution, deciphering the sensing and signaling of nutrient starvation response and their regulatory network provides options to develop nutrient uptake and utilization efficient crops. In the era of Omics, 'ionomics' provides the total elemental composition of the plant and is a powerful approach to the functional analysis of its genes and the gene networks. Besides, it is also essential to expose the students to various conventional and high-throughput phenotyping techniques to identify the nutrient efficient 'donors', traits and QTLs/ candidate genes to complement the research program on crop improvement.

V. Aim of the course

It provides knowledge on basic physiological processes governing nutrient uptake, physiological role of elements, factors influencing uptake, internal remobilization of nutrient element during starvation and adaptation strategies. Regulation of nutrient uptake and translocation would be studied at the molecular level providing information on genes and other signaling factors involved. The aim of this course is to make the students understand the physiological and molecular basis of nutrient uptake, translocation and utilization and to apply this knowledge in genetic improvement of crop plants.

The course is organized as follows:

No.	Blocks	Units	
1.	Mineral Nutrient: Classification, Function, Availability, Deficiency	1.	Mineral Elements: Classification, Function, Deficiency and Toxicity and Toxicity
2.	Nutrient Availability at Rhizosphere	2.	Nutrient Uptake, Translocation and
		1.	Ion Uptake Mechanisms Acquisition
		2.	Ion Transport to Shoot and Grains
		3.	Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Macronutrients
		4.	Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Micro and Beneficial Nutrients
		5.	Microbes, Fungal Association for Nutrient Acquisition
		6.	Nutrient Delivery
3.	Nutrient Efficiency of Crop	1.	Improving Nutrient Acquisition and Efficiency of Crops

VI. Theory

Block 1: Mineral Nutrient: Classification, Function, Availability, Deficiency and Toxicity

Unit 1: Mineral Elements: Classification, Function, Deficiency and Toxicity

Classification based on mobility and characteristic features; physiological role in regulating plant growth, metabolism, development and human health- Regulatory Dietary Allowance (RDA), Deficiency and toxicity of macro, micro and beneficial elements, Tolerance of plants to nutrient toxicity, hyper-accumulators of nutrients: Concept of phytoremediation.Unit 2: Nutrient Availability at Rhizosphere Biological and chemical reactions influencing nutrient availability near the root system, interaction between ions in the rhizosphere, Rhizosphere chemistry in relation to plant nutrition- chemical reactions, root exudates to mobilize nutrients.

Block 2: Nutrient Uptake, Translocation and Acquisition

Unit 1: Ion Uptake Mechanisms

Mineral salt absorption- chemical potential of solute- Nernst equation- passive uptake- diffusion, ion exchange-Donnan Equilibrium, mass flow of ions, Mediated transport- Facilitated diffusion-ionophores; membrane transport proteins- active transport-ion channels, Primary and secondary transport- carriers and pumps.

Unit 2: Ion Transport to Shoot and Grains

Long distance transport in plants - Mechanism of xylem and phloem transport, Radial movement of ions across the root, Mechanism of phloem transport, remobilization of mineral nutrients - phloem loading, phloem unloading.

Unit 3: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Macronutrients

Molecular structures of LAT and HAT, their localization and regulation by various eXternal factors, Nitrate transporters and their functional regulation - Nitrate transporters (NRT1, NRT2, dual-affinity nitrate transporter NRT1.1/CHL1), Phosphate transporters and their functional regulation - PT1/PHT1, PHT2, PHT3, PHT4, Potassium transporters and their functional regulation - KT/HAK/KUP family Ion transporters involved in transport of multiple elements, for eXample, sulphate transporter for Selenate transport, phosphate transporter for Arsenate transport, etc.

Unit 4: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Micro and Beneficial Nutrients

Plant Strategies: Different Strategies I & II adopted by plants for uptake of Fe under Fe deficient condition, Transporters and genes regulating uptake and transport of micronutrients, genes encoding transport/channel proteins, Examples of genes encoding mineral ion transporters for Zn, Fe, Mn, Cu, B, Mo, Ni, Cl, Na, Si, Se, Beneficial nutrients and their role in plant growth and development – Sodium, Silicon, and Cobalt.

Unit 5: Microbes, Fungal Association for Nutrient Acquisition

Microbes to improve nutrient availability – Bio-inoculation technology- P solubilizers and Zinc solubilizers in nutrient absorption, Microbial systems for biological nitrogen fixation – process of nodulation, biochemistry of N_2-fixation, Endophytes to improve nutrient availability, Mycorrhiza- Mycorrhizal symbiosis on nutrient uptake by root. Role of AMF on nitrogen, phosphorus and zinc uptake.

Unit 6: Nutrient Delivery

Foliar application of nutrients, absorption and their compartmentation, Concept of slow release fertilizers and chelates (organic and inorganic), Soil less cultures- aeroponics, hydroponics, fertigation.

Block 3: Nutrient Efficiency of Crop

Unit 1: Improving Nutrient Acquisition and Efficiency of Crops

Concept of nutrient uptake and use efficiency- Genotypic differences- physiology and molecular mechanisms, Nutrient use efficiency in selected crops, Root system architecture (RSA), root characters associated with nutrient acquisition, Genes and QTLs to improve nutrient acquisition and efficiency for important nutrients in few crop species, Transgenic and molecular breeding approaches to improve traits associated with acquisition and efficiency – Case studies, Biofortification strategies– for micronutrients, agronomic approaches, Influence of nutrition status on plant response to biotic and abiotic stresses.

VII. Practicals

- Techniques to develop the deficiency symptoms of nutrients –Hydroponics/ Aeroponics- diagno sis of deficiency symptoms in agriculturally important crop plants
- Physiological and biochemical markers to identify nutrient deficiency levels
- Biochemical markers for essential elements: Assay of nitrate reductase activity for N
- Estimation of chlorophyll concentration in leaves of N deficient and N sufficient plants
- Collection of acid phosphatase from root exudates and enzyme assay for P
- Measuring anthocyanin and chlorophyll pigments concentration in leaves for P
- Collection of organic acid in root exudates, characterization and quantification for P
- Assay of carbonic anhydrase activity for Zn
- Assay of SOD Activity for Cu, Zn and Mn
- Estimation of nitrogen concentration in plant tissue - Kjeldhal and Dumas method
- Estimation of phosphorus concentration in plant tissue – colorimetric method
- Estimation of potassium, magnesium and sodium concentration in plant tissue – flame photometer
- Estimation of micronutrients (Zn, Cu, Fe, Mn, Co etc) concentration in plant tissue– atomic absorption spectrometer/ ICP-OES
- Measurement of simple root traits such as root length, angle, volume, surface area, etc. (using conventional methods or root scanner and WinRhizo)
- Shovelomics' in the field grown crops (for measuring root architecture) and using 'ImageJ' for analysis
- Non-invasive techniques to quantify nutrients – XRF (X-Ray Fluorescence) and hyper spectral reflectance.

VIII. Teaching methods/ activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

– comprehend the fundamental concepts of mineral nutrition of plant.
– describe the physiological and molecular mechanisms of acquisition and translocation of nutrient.
– describe the basis of differential nutrient efficiency.

X. Suggested Reading

- Recommended Dietary Allowances: 10th Edition (https://www.ncbi.nlm.nih.gov/books/NBK234932/pdf/Bookshelf_NBK234932.pdf)
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- 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/)review of mechanisms and controls. Jour nal of Experimental Botany, 64(16), 4839-4850.
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I. Course Title : Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modelling

II. Course Code : PP 507

III. Credit Hours : 3(2+1)

IV. Why this Course?

Agronomic inputs and environmental factors enhance crop growth by improving photosynthetic processes and photosynthate partitioning. Carbon metabolism is the most important physiological process that has a direct influence on crop growth and productivity which is quite sensitive to biotic and abiotic constraints. Hence a comprehensive understanding canopy photosynthetic process is crucial. This is an important component in crop improvement program, especially in the scenario of plateauing yields. These photosynthetic processes and their response to environmental factors form the basis for developing growth and yield predicting models.

V. Aim of the Course

The course provides a comprehensive theoretical and hands on experience and expertise to students on various aspects of photosynthesis including biophysical, biochemical and molecular regulations. While canopy photosynthesis drives crop growth rates, factors associated with sink activity and partitioning determine productivity. Hence, adequate emphasis would be given to canopy photosynthesis, translocation and its feedback regulation, Crop growth and yield structure analysis and their responses to environmental factors. Growth and yield prediction models and their relevance will be adequately discussed.

The course is organized as follows:

No.	Blocks	Units
1.	Photosynthetic Processes	1. Canopy Architecture and Energy Utilization
		2. Photochemical Processes
		3. Biochemical Processes
		4. Product Synthesis and Translocation
		5. Growth and Yield forming Mechanisms
2.	Yield Improvement and Modelling	1. Molecular Options to Improve Photosynthesis, Growth and Productivity
		2. Fundamentals of Dynamic Simulation Models
		3. Description of Well-established Yield Models4.

VI. Theory

Block 1: Photosynthetic Processes

Examples of Robust Models Extensively Used

Unit 1: 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 2: 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: qN, qP, NPQ.

Unit 3: Biochemical Processes

CO_2 diffusion and resistances (gs and gm). Concept of Ci determining CO_2 diffusion. RuBisCO activation state, kinetics and catalytic properties, Carboxylation processes in C_3, C_4 and CAM plants and their relevance, CO_2 concentrating mechanisms and their importance in improving carbon assimilation, Ecological significance of C_4 and CAM photosynthesis, Photorespiration and Mitochondrial respiration and net carbon gain, Carbon isotope discrimination and its importance as a surrogate of Ci.

Unit 4: 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 un-loading.

Unit 5: 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 1: 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 C_3 plants and reducing photorespiration.

Unit 2: Fundamentals of Dynamic Simulation Models

Collection of crop specific genetic coefficient, Crop, soil and historic weather data

Unit 3: Description of Well-established Yield Models

Application and limitations of modeling, Yield prediction models such as APSYM, PeanutGrowetc, Machine learning approaches and IoT for making informed on- farm decisions.

Unit 4: Examples of Robust Models Extensively Used

Duncan'syield prediction model, Passioura'smodelfor growth maximising.

VII. Practicals

- Plant sampling for leaf area and biomass estimation; analysis of growth and yield parameters – LAD, NAR. CGR, LAI, LAR, SLA portioning 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 CO_2 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}
- CO_2 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

VIII. Teaching methods/activities

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

IX. Learning Outcome

After completion of this course students are expected to have in depth knowledge on Photosynthetic processes associated with product synthesis and yield development. Students will also obtain current knowledge on various crop models.

X. Suggested Reading

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General Source Information

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I. Course Title : Physiology of Field Crops

II. Course Code : PP 508

III. Credit Hours : 2(2+0)

IV. Why this course?

In recent years, phenomenal progress has been made in understanding plant processes which are crop specific. Genetic gain in productivity can be achieved only by improving plant physiological traits/ adaptive mechanisms. Even crop management should be based on sound physiological principles. For example, crop's response to the increase in global warming has to be looked from thermo morphogenesis concept in terms of GDD and its effect on phenological processes in some of the important field crops exposure on crop specific physiological processes is necessary and has particular significance.

V. Aim of the course

This course provides a broad exposure on the physiological aspects of field crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of field crop plants. Besides, the emphasis is on unique crop specific features.

Broad categories of crops that can be selected for this course are as follows.

1. Cereals– Rice, Wheat, Maize etc.
2. Millets– Finger millet, Sorghum etc.
3. Pulse crops– Green gram, Black gram, Lentil, Pigeon pea, Chickpeas, Cowpea, Beans etc.
4. Oilseed crops– Groundnut, Rapeseed Mustard, Soybean etc.
5. Sugarcane
6. Fibre crops– Cotton, Jute, Ramie, Hemp etc.

The course is organized as follows:

No.	Blocks	Units
1.	Physiology of Field Crops	1. Introduction
		2. Crop Establishment, Crop Growth and Development
		3. Reproductive Growth
		4. Seed Nutrient Quality
		5. Plant Nutrition
		6. Abiotic Stress Response
		7. Crop Specific Physiological Processes and Importance

VI. Learning outcome

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of field crops.

VII. Theory

Block 1: Physiology of Field Crops

Unit 1: Introduction

Origin- Variability in physiology of crop plants between wild species and cultivated. Adaptability to growing environments (ecosystems), Importance in food grain contribution.

Unit 2: Crop Establishment, Crop Growth and Development

Seed characteristic features, dormancy, viability, concept of seed priming seedling establishment and crop stand. Different crop growth stages, concept of source establishment and optimum LAI, Canopy architecture, light interception/radiation use efficiency, thermal time, heat units, GDD, determining growth duration.

Unit 3: Reproductive Growth

Photo and thermo-periodic response for flowering, sink development, sink source relationship, partitioning efficiency, improvement in HI, yield determining factors, genetic gain in yield over years, structuring of ideal plant type, limitations to improve source to sink size, options to improve yield potential.

Unit 4: Seed Nutrient Quality

Seed quality, seed as a source of nutrients, seed constituents and their improvement, concept of pathway engineering to improve seed quality.

Unit 5: Plant Nutrition

Nutrient requirement, genetic variability in nutrient acquisition under constraint conditions, specific nutrient disorders.

Unit 6: Abiotic Stress Response

Response to different abiotic stresses, plant traits/mechanics to improve adaptation to realize potential yields. Global warming responses, thermomorphogenesis, approaches to overcome the constraints.

Unit 7: Crop Specific Physiological Processes and Importance

Choosing location specific crop species exposure will be given on physiological process as described above. Besides, emphasis is on providing information on crop specific features/productivity constraints.

Teaching methods/activities

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

Suggested Reading

- Grain Legumes: Ed De Ron, Antonio M. (Ed.) 2015. Springer
- Legumes under Environmental Stress: Yield, Improvement and Adaptations. Eds MM Azooz P Ahmad and Hoboken, NJ: John Wiley and Sons, Ltd., 328 pages. ISBN: 978-1-118-917084
- Pulse Crops: Biotechnological Strategies to Enhance Abiotic Stress Tolerance. Ganeshan S, Gaur PM, Chibbar RN, Tuteja N, Gill SS, Tuteja R. chapter 17
- Climate Change and Management of Cool Season Grain Legume Crops. Eds Yadav GS, McNeil DL, Redden R, Patil SA. Springer
- Nature's pulse power: legumes, food security and climate change. Considine MJ, SiddiqueKHM and Foyer CH,. 2017 J Exp Bot. 68(8): 1815–1818. Published online 2017 May 11. doi: 10.1093/jXb/erx099

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- Reynolds M. Wheat Physiological Breeding volume I and II (CIMMYT): Wheat Physiological Breeding: A Field Guide to Wheat Phenotyping.
- Mamrutha HM et al. 2019. Physiological and Molecular Basis of Abiotic Stress Tolerance in Wheat. In: Rajpal V., Sehgal D., Kumar A., Raina S. (eds) Genetic Enhancement of Crops for Tolerance to Abiotic Stress: Mechanisms and Approaches, Vol. I. Sustainable Development and Biodiversity, vol 20. Springer, Cham
- Tiwari V. et al. 2017. Managing Abiotic Stresses in Wheat. In: Minhas P., Rane J., Pasala R. (eds) Abiotic Stress Management for Resilient Agriculture. Springer, Singapore

I. Course Title : Physiology of Horticulture Crops

II. Course Code : PP 509

III. Credit Hours : 2(2+0)

IV. Why this Course?

Improving physiological processes forms the basis to enhance the productivity or to improve a specific growth processes. Several interventions based on principals of physiological processes provide options to enhance crop productivity. Basic insight on photoperiodic response is crucial for determining planting dates. Understanding the mechanisms of rooting for vegetative propagation has lead in developing rooting hormones etc., In view of this, a comprehensive exposure on growth and development of horticulture crops and providing insights on major production constraints and physiological approaches to overcome is highly essential.

V. Aim of the Course

This course should provide a broad exposure on the physiological aspects of horticulture crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of horticultural crop plants. To describe basic and applied physiology behind the production and productivity of horticultural crops and their pre and postharvest management, ideal storage conditions, quality retention, processing and value addition.

Broad categories of crops that can be selected for this course are as follows.

1. Fruit crops: Mango, Grapes, Apple, Banana, Citrus etc.
2. Vegetable crops: Tomato, Onion, Brinjal, Cauliflower, Okra etc.
3. Tuberous crops: Potato, Cassava, Sweet potato, Yam etc.
4. Plantation crops: Coconut, Oil palm, Cashew, Tea, Coffee, Rubber, Areca nut, Cocoa etc.
5. Floriculture crops: Rose, Marigold, Carnation, Chrysanthemum, Gladiolus, Orchids, Tuberoseetc.
6. Other groups: Medicinal crops, Aromatic crops, Spices crops.

The course is organized as follows:

No.	Blocks	Units
1	Physiology of Horticultural Crops	1. Introduction
		2. Crop growth and Development
		3. Reproductive Growth
		4. Pre and Post-harvest Physiology
		5. Plant Nutrition and Abiotic Stress Responses
		6. Specific Aspects and Unique Crop Features

VI. Learning outcome

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of horticultural crops.

VII. Theory

Block 1: Physiology of Horticultural Crops

Unit 1: Introduction

Origin, distribution and adaptability of crops to different agro-climatic conditions

Unit 2: Crop growth and Development

Internal factors (hormone, etc.) influencing various physiological processes linked to vegetative growth of growth of specific organ, correlative and algometric growth External factors (water, nutrition, temperature, etc.) influencing various physiological processes linked to vegetative growth or growth of specific organ, correlative and algometric growth, Propagation methods, grafting, cutting, budding, air layering. Physiology of pruning, dwarfing, branch bending, canopy management etc., Physiological and biochemical aspects of scion and root stock interaction and compatibility.

Unit 3: Reproductive Growth

Physiology of flowering, photo- and thermo-periodism and response to vernalization, Factors influencing reproductive growth, fruit and seed set/retention, physiology of flower sex ratio, Physiological processes governing source-sink relationship and productivity.

Unit 4: Pre and Post Harvest Physiology

Preharvest factors influencing postharvest physiology, Physiological and molecular mechanisms of ripening, Physiological and molecular mechanisms of senescence, Hormonal and chemical control of postharvest deterioration of fruits/vegetable/ flowers. Regulation of ripening at physiological and molecular levels, Regulation of senescence at physiological and molecular levels, Approaches to improve shelf life and storability. Approaches to improve postharvest management, Approaches to improve processing and value addition.

Unit 5: Plant Nutrition and Abiotic Stress Responses

Nutrient acquisition and requirement, plant phenology and nutrient requirement; Role of rootstocks in nutrient acquisition and in abiotic stress tolerance, Adaptive mechanisms and approaches to improve performances under drought and high temperature, Adaptive mechanisms and approaches to improve performances under frost, chilling and nutrient deficient conditions, Root physiology in abiotic stress tolerance.

Unit 6: Specific Aspects and Unique Crop Features

Specific aspects

Polyhouse cultivation, Hormones/PGRs for improving crop performance, Major and micronutrients for improving crop performance, Light interception, shade regulation, dwarfing root stocks, Chilling requirement for flowering, photoperiodic response, pollen viability, stigma receptivity, Flower (blossom) and fruit drop.

Unique crop features

Maturity and maturity indices, Source-sink relations, Vegetative propagation, Physiology of tuberization and rhizome initiation and formation, Virus free planting material, Bulbs/tubers dormancy, bud break, Physiological disorders, Storage, Packaging, Quality.

VIII. Teaching methods / activities

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

IX. Suggested Reading

- Sethuraj MR and Raghavendra AS. 2012. Tree Crop Physiology. ISBN-13: 978-0444428417, ISBN-10: 0444428410, Elsevier Science Publishers.
- Bhatnagar P. Physiology of Growth and Development of Horticultural Crops, ISBN-10: 817754666X, ISBN-13: 978-8177546668
- Singh A. Fruit Physiology and Production, ISBN-10: 8127211788, ISBN-13: 978-8127211783, Kalyani Publishers; 5th edition (March 28, 2003).
- Hare K. 2012. Physiology of Fruit Production, ISBN-10: 9380012373, ISBN-13: 978-9380012377, Studium Press India Pvt. Ltd
- Durner EF. 2013. Principles of Horticultural Physiology, ISBN-13: 978-1780643069, ISBN-10: 1780643063, CABI.
- Bleasdale JKA. Plant Physiology in Relation to Horticulture, ISBN-10: 8192686094, ISBN- 13: 978-8192686097, SENTIFIC (2014) 2nd edition
- Kumar M. 2015. Physiology of Fruit Production, ISBN-10: 9384568384, ISBN-13: 978-9384568382.
- Yahia EM and Carrillo-Lopez A. 2018. Postharvest Physiology and Biochemistry of Fruits and Vegetables, ISBN-10: 0128132787, ISBN-13: 978-0128132784, Woodhead Publishing.
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Grapes

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Guava

- Rodrigues AAM, Silva SDM, Dantas AL, Silva AFD, Santos LDS and Moreira DDN. 2018. Physiology and postharvest conservation of 'Paluma'guava under coatings using Jack fruit seed-based starch. RevistaBrasileira de Fruticultura, 40(2).
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- Adhikari S and Kandel TP. 2015. Effect of time and level of pruning on vegetative growth, flowering, yield, and quality of guava. International Journal of Fruit Science, 15(3) 290-301.
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- Adhikari S. 2012. Guava Pruning and Its Physiology

Tomato

- Aivalakis G and Katinakis P. 2008. Biochemistry and molecular physiology of tomato and pepper fruit ripening. Eur J Plant SciBiotechnol, 2(special issue 1), 145-155.
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Onion

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- Currah L, Cools K and Terry LA. 2012. Onions, shallots and garlic. Teoksessa: Rees, D., Farrell, G. and Orchard, J.(toim.). Crop post-harvest: science and technology, 3, 360-391.
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- Coolong TW. 2007. Physiological Factors Affecting Onion (Allium Cepa L.) Storability: Cultural Methods for Improving Postharvest Quality, University of Georgia.
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- Khokhar KM. 2014. Flowering and seed development in onion—A review. Open Access Library 1(07).

Brinjal

- Sharma SP and Brar JS. 2008. Nutritional requirements of brinjal (Solanum melongena L.)- A review. Agric. Rev, 29(2), pp.79-88.
- Byari, S.H. and Al-Rabighi, S.M., 1995. Morphological and physiological responses of egg plant cultivars (Solanum melongena L.) to drought. J. KAU: Met. Env, Arid Land Agric. Sci, 6, pp.41-47.

I. Course Title : Seed Physiology

II. Course Code : PP 510

III. Credit Hours : 3(2+1)

IV. Why this course ?

Seeds are considered as propagule and as a major source of nutrition for humans and other animals. Therefore, all information concerning their nutritive value, chemical composition; storability, retention of viability are very important. Looking into the importance of seeds, emphasis has been given to produce high quality seeds with excellent genetic potential to improve seed germination and to produce vigorous seedlings. In fact, recently techniques are employed to raise healthy and vigorous seeds to obtain vigorous seedlings. Several hormones and chemicals are used to improve the oil, protein, and other economic attributes of seeds. Therefore, to give more insight into the development of quality seeds and also protecting them without losing much of nutritive value, this course has been proposed.

V. Aim of the course

This course will approach the subjects from two perspectives –physiology of seed development and seed germination. It aims to describe students the physiological processes involved in regulation and mechanism of seed development, dormancy and germination. Further, to provide an insight into physiological processes governing seed quality and its survival. Accordingly.

The Course is organized as follows:

No.	Blocks	Units
1.	Physiology of Seed Development	1. Introduction to Seed Physiology
		2. Seed Development
		3. Seed Maturation
		4. Metabolism in Developing Seed
2.	Physiology of Seed Germination and Dormancy	1. Seed Germination
		2. Seed Dormancy and Viability

VI. Theory

Block 1: Physiology of Seed Development

Unit 1: Introduction to Seed Physiology

Importance of seed as a propagule, seed structure and functions; chemical composition of seeds. Embryogenesis: pollination and fertilization, pollen and pistil interaction, signal for interaction; pollen load hypothesis; genetical and environmental influence on seed development. Source-Sink relationship affecting seed yield and quality. Concept of seed viability and seedling vigour and their relevance; approaches to improve the storability of seeds. Physiological and molecular mechanisms of seed germination; approaches to improve seed germination; seed size and its influence on seed germination.

Unit 2: Seed Development

Physiology and molecular mechanisms of embryo, endosperm and seed coat development; cellularization during endosperm development; morphological and cellular changes during seed coat development, anatomy and function of seed coat, programmed cell death (PCD) in seed coat, Deposition of seed storage reserves during development.

Unit 3: Seed Maturation

Seed maturation and maturation indices; physiological and anatomical changes during seed maturation; Seed drying and acquisition of desiccation tolerance in seeds; mechanisms of desiccation tolerance; role of ABA LEA's, HSP's, dehydrins and other stress proteins during seed maturation and drying, Seed abortion and approaches to reduce it.

Unit 4: Metabolism in Developing Seed

Chemical composition of seeds (carbohydrates, proteins, fats etc.), source of assimilates for seed development, pathways of movement of assimilates to developing seed, approaches to increase the chemical composition of seeds. Seed respiration and mitochondrial activity; seed respiration rate and storability of seeds. Seed ageing, Mobilization of stored resource in seeds; Chemistry of oxidation of starch, proteins and fats; Utilization of breakdown products by embryonic axis.

Block 2: Physiology of Seed Germination and Dormancy

Unit 1: Seed germination

Seed germination, types of germination, imbibition kinetics of germinating seed; Physiological events during germination: seed respiration, mitochondrial activity, mobilization of food reserve; energy utilization by the germinating seed.

Environmental regulation of germination: hydro-time, thermal time and hydrothermal time models; Influence of environmental factors on germination; Role of plant hormones/PGR's during seed germination.

Unit 2: Seed Dormancy and Viability

Physiological and molecular basis of seed dormancy, hormonal regulation of dormancy, After ripening, dormancy breaking treatments; Ecological perspective of seed dormancy. Seed viability: concept and physiology of seed viability, theories of seed ageing, seed storage and regulation of storage life of seeds; methods to prolong seed viability; Conservation of orthodox and recalcitrant seeds. Seed vigour: concept, importance, measurement; Physiological, biochemical and molecular basis of seed vigour.

VII. Practicals

- Determination of seed reserves: carbohydrates, proteins and lipids
- Study of different seed structures
- Kinetics of seed imbibition; Seed germination test, enzymatic activities and respiration during germination and vigour testing methods etc.
- Accelerated ageing test to know the seed vigour and storability
- Measurement of seed moisture content
- Determination of amylase activity in germinating seeds
- Measurement of electrical conductivity in seed leachate
- Measurement of seed viability using tetrazolium chloride
- Determination of dehydrogenase activity
- Seed germination study- Determination of Germination IndeX and seedling growth
- Measurement ofseed vigour indeX
- Dormancy breaking treatments
- Seed priming techniques
- Effect of environmental stresses on seed germination and seedling growth
- Effect of hormones on seed germination

VIII. Teaching methods/activities

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

IX. Learning outcome

At the end of the course the students are eXpected to be able to understand the physiology of seed development and seed germination. The students will be able to identify the physiological processes involved in regulation of seed development, dormancy and germination.

X. Suggested Reading

- Bewley, JD, Bradford K, Hilhorst H, Nonogaki H. (2013). Seeds: Physiology of Development, Germination and Dormancy, Springer-Verlag.
- Larkins BA and Vasil IK (Ed), Cellular and Molecular Biology of Plant Seed Development, 2010, Springer.
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- Prakash. M. 2011. Seed physiology of crops.(ed). Satish Serial Publishing house, New Delhi.
- Roberto Benech-Arnold, Rodolfo Sanchez. 2004. Handbook of Seed Physiology: Applications to Agriculture. CRC Press.
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- Padmavathi SM, Prakash S, Ezhil Kumar G, Sathianarayanan and Kamaraj A. 2012. A Text Book of Seed Science and Technology. New India Publishing Agency, New Delhi.
- Tina Steinbrecher Gerhard Leubner-Metzger. 2017. The biomechanics of seed germination. Journal of Experimental Botany, 68(4): 765–783.
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I. Course Title : Phenotyping Physiological Processes

II. Course Code : PP 511

III. Credit Hours : 2(2+0)

IV. Why this course?

One of the main mandates of SAU and crop specific institutes is crop improvement. Seed industry and academic institutes need contribution from physiologists on these aspects. Conceptual changes in breeding approaches in terms of breeding for specific physiological traits necessitates that the students develop conceptual approaches for phenotyping in different physiological processes. Characterizing the parents, germplasm accessions, segregating populations for specific physiological traits like flowering response, variation in root system architecture, etc is crucial for genetic enhancement of these traits. This student ready Course can contribute richly to research and development of the seed sectors and crop specific institutions where the major emphasis in recent years is genetic enhancement of traits.

V. Aim of the course

The major emphasis in this course is to phenotype well characterized physiological processes/ plant traits associated with plant growth, development and productivity, besides, comprehensive approach to precise imposition of various abiotic stresses and capture genetic variability in adaptive traits. The aim is to employ these techniques for crop improvement programs.

The course is organized as follows:

No.	Blocks	Units
1.	Phenotyping Physiological Processes	1. Concept of Phenotyping
		2. Phenotyping for Traits for Crop Establishment
		3. Concept and Approaches to Identify Genotypes with Superior Growth Rate
		4. Identifying Photo-insensitive Genotypes- options and Approaches
		5. Identifying Thermo-insensitive Genotypes- options and Approaches
		6. Yield Structure Analysis- Relevant Yield Attributes
		7. Source-sink Relationship- Assessment of Limitation
		8. Identify Genetic resources for Abiotic Stress Constraints

VI. Theory

Block 1: Phenotyping Physiological Processes

Unit 1: Concept of Phenotyping

Phenotyping technologies are essential component for assessing plant responses, identify superior trait donors, mitigation responses, trait introgression and trait based breeding.

Unit 2: Phenotyping for Traits for Crop Establishment

Seed viability, seed dormancy, seed hydration rates, seed density and weight, Seedling vigour in normal and adverse conditions.

Unit 3: Concept and Approaches to Identify Genotypes with Superior Growth Rate

Phenotyping for leaf expansion, leaf area index, light interception and crop extinction coefficient. Pigment quantification for nitrogen and chlorophyll status - SPAD, anthocyanin and flavonoids – Duolex. Growth rates by non-invasive techniques like NDVI, Concept of Net assimilation rate and DM/LAD; surrogates for photosynthetic traits; stomatal characteristic.

Unit 4: Identifying Photo-insensitive Genotypes-options and Approaches

Exposing to longer and shorter photoperiod by staggered sowing; extending the day length- light interception by red light; days to heading/ anthesis, approaches for synchronization of flowering.

Unit 5: Identifying Thermo-insensitive Genotypes-options and Approaches

Altering total degree days- staggered sowing at lower latitudes or by growth chambers; quantifying heading, anthesis, maturity and grain filling days, grain number and weight, grain filling rate.

Unit 6: Yield Structure Analysis- Relevant Yield Attributes

Pollen biology, stigma receptivity, spikelet sterility (cereals), floral abscission (other crops), fruiting points / productive tillers, number of grains/ fruits per panicle/ inflorescence and grain characteristic. Phenotyping for lodging- culm traits, intermodal length, lignification, Phenylalanine ammonia lyase (PAL) and Tyrosine ammonia lyase(TAL). Approaches to identify genetic resources with traits to improve yield potential.

Unit 7: Source-sink Relationship- Assessment of Limitation

Phenotyping for source-sink size, Concept of sink-source limitation- defloration and defoliation. Remobilization of stored metabolites and concept of stay green; estimation of water soluble carbohydrates; partitioning coefficient and harvest index.

Unit 8: Identify Genetic Resources for Abiotic Stress Constraints

Approaches for precise stress imposition to diverse stresses, Identify trait donor lines for different stresses: approaches by Stress Susceptibility Index (SSI), Stress Induction Response (SIR), Capturing variability for adaptive traits: root traits,stomatal factors/wax, osmolyte, surrogate approach for acquired tolerant traits, Flowering response, Spikelet fertility, Abscission and Senescence, Screening high density response-based on SSI – root adaptation and Shade Avoidance Response (SAR).

VII. Teaching methods/activities

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

VIII. Learning outcome

After completion of this course students are expected to develop clear concept and insight into phenotyping technologies associated with plant growth, development and productivity.

IX. Suggested Reading

- Kumar J, Pratap A and Kumar S. 2015. Plant Phenomics: An Overview. 10.1007/978-81- 322-2226-2_1.
- Pratap A, Gupta S, Nair RM, Gupta SK, Schafleitner R, Basu PS, Singh CM, Prajapati U, Gupta AK, Nayyar H, Mishra AK, Baek KH. 2019. Using Plant Phenomics to Exploit the Gains of Genomics. Agronomy 9, 126.
- AOSA. 2009. Seed Vigor Testing Handbook. Contribution No. 32 to the Handbook on Seed Testing.
- Finch-Savage WE and Bassel GW. 2015. Seed vigour and crop establishment: extending performance beyond adaptation. Journal of experimental botany, 67(3), 567-591.

- Muñoz-Huerta R, Guevara-Gonzalez R, Contreras-Medina L, Torres-Pacheco I, Prado- Olivarez J and Ocampo-Velazquez R. 2013. A review of methods for sensing the nitrogen status in plants: advantages, disadvantages and recent advances. sensors, 13(8), 10823-10843.
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- Ouzounis, T., Rosenqvist, E., and Ottosen, C., 2015. Spectral Effects of Artificial Light on Plant Physiology and Secondary Metabolism: A Review American Society Horticulture Science. 50(8); 1128–1135 doi.org/10.21273/HORTSCI.50.8.1128
- The Flowering Response of the Rice Plant to Photoperiod: A Review of The Literature Fourth Edition.
- Sehgal A, Sita K, Siddique KH, Kumar R, Bhogireddy S, Varshney RK and Nayyar H. 2018. Drought or/and Heat-Stress Effects on Seed Filling in Food Crops: Impacts on Functional Biochemistry, Seed Yields, and Nutritional Quality. Frontiers in Plant Science, 9.
- Prasad, P. V., Bheemanahalli, R., andJagadish, S. K. 2017. Field crops and the fear of heat stress—Opportunities, challenges and future directions. Field Crops Research 200, 114-121.
- Gómez JF, Talle B and Wilson ZA. 2015. Anther and pollen development: a conserved developmental pathway. Journal of Integrative Plant Biology 57(11), 876-891.
- Khobra R, Sareen S, Meena BK, Kumar A, Tiwari V and Singh GP. 2019. Exploring the traits for lodging tolerance in wheat genotypes: A review. Physiology and Molecular Biology of Plants, 1-12.
- Hirano K, Ordonio RL and Matsuoka M. 2017. Engineering the lodging resistance mechanism of post-Green Revolution rice to meet future demands. Proceedings of the Japan Academy, Series B, 93(4), 220-233.
- White, A. C., Rogers, a., Rees, M and Osborne, C.P., 2016. How can we make plants grow faster? A source–sink perspective on growth rate Journal of Experimental Botany, 67(1): 31– 45.
- Ragheba, A., El-Shimyb, H and Raghebb, G. 2016. Green architecture: a concept of sustainability, Procedia - Social and Behavioral Sciences 216: 778 – 787.
- Wang J, Wu G, Zhao B, Wang B, Lang Z, Zhang C and Wang H, 2016, Regulatory modules controlling early shade avoidance response in maize seedlings, BMC Genomics17: 269, https://doi.org/10.1186/s12864-016-2593-6.
- Carriedo, L., Maloof, J and Brady, S. 2016. Molecular control of crop shade avoidance. Current Opinion in Plant Biology. 30. 151-158. 10.1016/j.pbi.2016.03.005.

I. Course Title : Crop Growth Regulation and Management

II. Course Code : PP 512

III. Credit Hours : 2(2+0)

IV. Why this Course?

Besides crop improvement, the approach to regulate physiological processes for improving crop production made very good leads in recent years. The focus is to employ the basic knowledge of several physiological processes to manipulate the plant growth and specific processes like ripening, flowering to achieve higher economic yields. This dynamic course will address many of these technologies that are being developed for crop production based on principles of plant physiological processes. Training the students in this student ready coursewill provide the required practical knowledge which will be of immense relevance to contribute private agricultural sectors and for agri-based industries.

V. Aim of the Course

A comprehensive information needs to be provided in this course like light regulation in polyhouse cultivation, photoperiod responses by red/far red light for synchronizing flowering, techniques for soil less culture like aeroponics, pollen biology and hybrid production, chemical regulation of plant growth processes like flower initiation, flower sex, flower drop, fruit maturity, ripening and shelf-life, etc.

The course is organized as follows :

No.	Blocks	Units	
1	Propagation - Crop Establishment	1.	Seed as a Propogule
		2.	Vegetative Propogule
2	Regulation of Plant Growth	1.	Regulation of Plant Growth and Flowering Processes
		2.	Fruit Ripening and its Regulation
		3.	Concept of Senescence and its Retardation
3	Protective Cultivation–Stress	1.	Protective Cultivation Interventions to Alter Mitigation Physiological Processes and Growth
		2.	Drought Mitigation Options and Approaches
		3.	Specific Plant Processes Regulated by Chemicals and Growth Hormones

VI. Theory

Block 1: Propagation - Crop Establishment

Unit 1: Seed as a Propogule

Concept of improving seed characteristics for crop establishment. Mechanisms of regulating seed dormancy, precocious germination, ways to control pre-harvest sprouting in crop plants. Seed viability and its regulation, factors to minimize loss of viability and improve seedling vigour. Concept of seed priming, techniques of priming, seed priming to induce tolerance to stresses. Role of media, nutrition and PGPR's on seedling vigour and subsequent crop establishment.

Unit 2: Vegetative Propogule

Chemical and hormonal regulation of vegetative propagation. Regulation of rooting, bud sprouting, Bulb/tuber dormancy. Chemical regulation of graft union. Concept of in vitro micropropogation.

Block 2: Regulation of Plant Growth Processes

Unit 1: Regulation of Plant Growth and Flowering

Chemical and hormonal regulation of plant architecture, tillering, branching, bud breaking, Regulation of flowering by photo and thermoperiod, nutrients, chemicals and hormones, concept of speed breeding, Flowering synchrony in hybrid seed production, Sex ratio alteration, flower and fruit thinning, Pollen viability in relation to environment, harvesting, storage and transportation, Prevention of abscission, flower and fruit drop, seed and fruit growth regulation- role of hormones.

Unit 2: Fruit Ripening and its Regulation

Approaches to improve shelf life – storage environment, water loss, respiration, Modified atmosphere, gaseous environment for storage, storage disorders, chilling injury.

Unit 3: Concept of Senescence and its Retardation

Physiology of senescence and options to regulate, Chemical regulation of senescence, maintenance of chlorophyll during storage, role of hormones/micronutrients in reducing senescence, Concept of stay green, advantages and limitations. Relevance of stay green traits in plant breeding for crop improvement.

Block 3: Protective Cultivation–Stress Mitigation

Unit 1: Protective Cultivation Interventions to Alter Physiological Processes and Growth

Spectral characteristics of light in polyhouse, light regulation to optimize plant photosynthetic and photomorphogenic processes and plant growth, LED sources of monochromatic light to regulate growth, etiolating and flowering, High temperature induced thermomorphogenic processes, Artificial growing media, soilless cultures, aeroponics, fogoponics, Concept of CO2 fertilization. Effect of humidity on leaf expansion and growth.

Unit 2: Drought Mitigation Options and Approaches

Moisture conservation options at soil and plant level, Concept of increasing water holding capacity, role of Hydrogels – water and mineral nutrients release pattern. Approaches to improve transpiration over evapo-transpiration, stomatal and non- stomatal regulation of water loss, antitranspirants, Osmoprotectants, ROS scavengers, plant nutrients, Root stocks in improving tolerance, Chemical regulation of flower drop due to temperature, Chemicals to improve pollen viability during abiotic stress.

Unit 3: Specific Plant Processes Regulated by Chemicals and Growth Hormones

Rooting of cuttings, Wine brewing industry, Promotion of gynoecious flower, Hybrid rice production, Induction of flowering in pine apple, cucurbits, Delaying ofsenescence and ripening, Production of dwarf plant for ornamental purpose, Reduction in flower and fruit drop, Increase in berry size in grapes.

VII. Teaching methods/activities

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

VIII. Suggested Reading

- Wu x, Ning F, Hu x and Wang W. 2017. Genetic Modification for Improving Seed Vigor Is Transitioning from Model Plantsto Crop Plants. Front. Plant Sci. 8: 8. doi: 10.3389/ fpls.2017.00008
- William E. Finch-Savage and Steven Footitt. 2017. Seed dormancy cycling and the regulation of dormancy mechanisms to time germination in variable field environments Journal of Experimental Botany, 68, (4), 843 856, https://doi.org/10.1093/jXb/ erw477
- Afzal I, Ur Rehman H, Naveed M and ShahzadMaqsood, Basra A. 2016. Recent Advances in Seed Enhancements Intech.
- Techniques and Experiments Plant Tissue Culture Techniques and Experiments Elsevier Inc.2013.
- Nanda AK and Melnyk CW. 2018. The role of plant hormones during grafting. Plant Res. 131(1): 49–58. doi: 10.1007/s10265-017-0994-5PMCID: PMC5762790
- Casa JJ and Balasubramanian. SK 2019. Thermomorphogenesis, Annual Review of Plant Biology, 70: 321-346 https://doi.org/10.1146/annurev-arplant-050718-095919

- Halevy AH. 2018. Handbook of Flowering. VCRC press
- Watson A, Ghosh S, Lee T. Hickey. 2018. Speed breeding is a powerful tool to accelerate crop research and breeding. Nature Plants 4, 23–29.
- Kusumaningrum D, Lee SH, Lee WH, Mo C., and Cho, B. K. 2015. A review of technologies to prolong the shelf life of fresh tropical fruits in Southeast Asia. Journal of Biosystems Engineering 40(4), 345-358.
- Sandarani, MDJC, Dasanayaka DCMCK and Jayasinghe CVL. 2018. Strategies Used to Pro ong the Shelf Life of Fresh Commodities. J AgriSci Food Res 9: 206.
- Falagán, N and Terry LA. 2018. Recent advances in controlled and modified atmosphere of fresh produce. Johnson Matthey Technology Review 62(1), 107-117.
- Kim, J., Kim, J. H., Lyu, J. I., Woo, H. R., and Lim, P. O. 2017. New insights into the regulation of leaf senescence in Arabidopsis. Journal of experimental botany 69(4), 787-799.
- Luche, H. D. S., Silva, J. A. G. D., Maia, L. C. D., and Oliveira, A. C. D. 2015. Stay-green: a potentiality in plant breeding. Ciência Rural, 45(10), 1755-1760.
- Bian, Z., Jiang, N., Grundy, S. and Lu, C., 2017. Uncovering LED light effects on plant growth: new angles and perspectives-LED light for improving plant growth, nutrition and energy-use efficiency. In International Symposium on New Technologies for Environment Control, Energy-Saving and Crop Production in Greenhouse and Plant 1227. 491-498.
- Barrett, G.E., AleXander, P.D., Robinson, J.S. and Bragg, N.C., 2016. Achieving environmentally sustainable growing media for soilless plant cultivation systems–A review. Scientia horticulturae, 212: 220-234.
- Raviv, M., Lieth, J.H. and Bar-Tal, A. (eds), 2019. Soilless Culture: Theory and Practice: Theory and Practice. Elsevier.
- Wang, P., Deng, Y., Li, X.Y., Wei, Z., Hu, X., Tian, F., Wu, X., Huang, Y., Ma, Y.J., Zhang, C. and Wang, Y. 2019. Dynamical effects of plastic mulch on evapotranspiration partitioning in a mulched agriculture ecosystem: Measurement with numerical modeling. Agricultural and Forest Meteorology, 268: 98-108.
- GernotBodner, Alireza, Hans-Peter Management of crop water under drought: A review. Agronomy for sustainable development. 2: 401-442

SEED SCIENCE AND TECHNOLOGY

M.Sc. (Agri) in Seed Science and Technology

Course Code	Course Title	Credit Hours
SST 501	Seed Developmental Biology	2 (1+1)
SST 502	Seed Dormancy and Germination	2 (1+1)
SST 503	Seed Production Principles and Techniques in Field Crops	3 (2+1)
SST 504	Seed Production Principles and Techniques in Vegetable Crops	3 (2+1)
SST 505	Seed Production Techniques in Fruits, Flowers,	3 (2+1)
	Spices, Plantation and Medicinal Crops	
SST 506	Seed Production Techniques in Forage, Pasture and Green Manure Crops	2 (1+1)
SST 507	Seed Legislation and Certification	3 (2+1)
SST 508	Post Harvest Handling and Storage of Seeds	3 (2+1)
SST 509	Seed Quality Testing and Enhancement	2 (1+1)
SST 510	Seed Technology of Tree Species	2 (1+1)
SST 511	Seed Industry and Marketing Management	2 (1+1)
SST 512	Seed Health Testing and Management	2 (1+1)

Course Contents
M.Sc. (Agri) in Seed Science and Technology

I. Course Title : Seed Developmental Biology

II. Course Code : SST 501

III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed is the most complex and successful unit of reproduction in flowering plants. Seed contains genetic wisdom of the past and act as an agent of genetic transfer from generation to generation. Basic knowledge on seed developmental biology will enable the learners to understand the structure of seed to take up research in seed science and technology.

V. Aim of the course

To acquire knowledge on development and maturation of essential structures of seed and their influence on seed quality.

VI. Theory

Unit I

Floral biology – types of pollination, mechanisms; sporogenesis – micro and mega sporogenesis; gametogenesis – development of male and female gametes and their structures; pollination and fertilization – mode of pollination, double fertilization, factors affecting pollination, fertilization; self-incompatibility and male sterility.

Unit II

Embryogenesis – development of monocot and dicot embryos – embryo plane formation – development of endosperm, cotyledons and seed coat – hard seed;apomixis – identification, classification, significance and its utilization; poly-embryony – types and significance; haplontic and diplontic sterility system, causes of embryo abortion, embryo rescue technique; somatic embryogenesis.

Unit III

Seed development – source of assimilates – mechanism of translocation; chemical composition – synthesis and deposition of storage reserves – starch, protein, fat and secondary metabolites – hormonal regulation.

Unit IV

Maturation drying – orthodox and recalcitrant seeds – desiccation tolerance – mechanism – structural changes during desiccation – role of LEA protein.

Unit V

Seed maturity indices – physiological and harvestable maturity; biotic and abiotic factors influencing seed development – development of hard seeds.

VI. Practical

- Study on floral biology of monocot;

- Study on floral biology of dicot plants;
- Study on pollen morphology of different crops;
- Pollen germination and viability test in major crops;
- Seed embryo and endosperm development in monocots;
- Seed embryo and cotyledon development in dicots;
- Anatomy and morphology of seed coat during development;
- Hard seed coat development;
- Study on external and internal structures;
- Seed development and maturation in agricultural crops – physical and physiological changes;
- Seed development and maturation in horticultural crops – physical and physiological changes;
- Study of biochemical changes during seed development and maturation in agricultural crops;
- Study of biochemical changes during seed development and maturation in horticultural crops;
- Study on physiological and harvestable maturity and maturity indices in different crops;
- Study on acquisition of seed dormancy and germination at different stages of maturity;
- Preparation of seed album and identification of seeds.

VII. Teaching methods

- Classroom lectures
- Slide shows
- Student assignments and presentation
- Group tasks
- Field and laboratory experiments
- Field visits

VIII. Learning outcome

Successful completion of this course enable student to take up advanced research on seed developmental biology and understanding on fundamental aspects of gametogenesis, seed development and maturity.

VII. Suggested Reading

- Adkins SW, Ashmore SE and Navi SC. 2007. Seeds: Biology, Development and Ecology. CAB International, Oxfordshire, UK.
- Bewley JD and Black M. 1994. Seeds: Physiology of Development and Germination. Springer, New York.
- Bewley JD, Bradford KJ, Hilhorst HWM and Nanogaki H. 2013. Seeds: Physiology of Devel opment, Germination and Dormancy. Springer, New York.
- Black M, Bewley JD and Halmer P. 2006. The Encyclopedia of Seeds: Science, Technology and Uses. CAB International publications, UK.
- Chhabra AK. 2006. Practical Manual of Floral Biology of Crop Plants. Department of Plant Breeding, CCSHAU, Hisar.

  Copeland, LO and McDonald MB. 2001. Principles of Seed Science and Technology. 4th Ed.
- Kluwer Academic publishers, USA.
- Frankel R and Galun E. 1977. Pollination Mechanisms, Reproduction and Plant Breeding.
- Springer Verlag, New York.

- Hesse MH, Haidemarie R, Zettler M, Webber R, Buchner AR, Radivo and Ulrich S. 2009. Pollen Terminology.
- An illustrated hand book. Springer Verlag, New York.
- Kozlowski. TT. 2012. Seed Biology: Importance, Development and Germination. (Vol. I). Academic Press Inc., New York.
- Maiti RK, Sarkar NC and Singh VP. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.

VIII. Suggested e-books

- https://www.springer.com/in/book/9783642810619
- https://www.springer.com/in/book/9780792373223
- https://www.springer.com/gp/book/9780792346456
- https://www.cabi.org/bookshop/book/9780851997230
- https://www.worldcat.org/title/seed-development-and-germination/oclc/44954614
- https://books.google.co.in/books/about/Seeds.html?id=-Zbzr1F_z74C&redir_esc
- https://books.google.co.in/books/about/Seeds.html?id=6S75BwAAQBAJ& printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false

IX. Suggested websites

- https://agriinfo.in/botany/18/
- http://www.seedbiology.de/structure.asp
- http://www.fao.org/3/ad232e/AD232E02.htmsbc.ucdavis.edu/Research_pages Seed_physiology_and_technology/
- https://courses.lumenlearning.com/wm-biology2/chapter/development-seeds-fruit www.iari.res.in/index.php?option=com_content&view=article&id=449& Itemid=137

I. Course Title : Seed Dormancy and Germination

II. Course Code : SST 502

III. Credit Hours : 2 (1+1)

IV. Why this course?

Physiology and bio chemistry of dormancy and germination is basic science in the field of Seed Science and Technology. Complete understanding on the mechanisms of acquisition and release of dormancy and germination enable the students to take up research on advanced aspect which may helpful to design the seed for our requirement.

V. Aim of the course

To impart knowledge on significance, mechanism of dormancy, induction and release of seed dormancy and germination, types and factors influencing germination and their management.

VI. Theory

Unit I

Seed dormancy – definition, concept and theories – significance – evolution; classification and mechanism of dormancy – ecological singnificance.

Unit II

Induction of dormancy during development – hormonal, physiological, molecular and genetic control of dormancy – maternal and paternal contribution; environmental factors influencing dormancy induction and release – seasonal influence – winter and summer annuals – secondary dormancy induction mechanism; artificial induction of dormancy and release; soil seed bank – natural release of dormancy and its mechanism; dormancy breaking – principles and methods.

Unit III

Seed germination – types and phases of germination; imbibition – pattern and water kinetics – events of germination – physical, physiological, biochemical changes -aerobic and anaerobic respiration quiescent.

Unit IV – Physiological and biochemical changes

Enzyme activation – mechanism – factors affecting enzyme activation – breakdown of stored materials – starch, protein and fat – energy generation – mobilization of storage reserves – changes in phenolic compounds.

Unit V – Molecular and genetic mechanisms

Molecular and genetic control of seed germination – auto tropism; factors affecting germination – media – temperature – light – gases; in-situ and viviparous germination – causes and mechanism – pattern of seed germination – tri-phasic curve.

VII. Practical

- Seed dormancy – identification of dormancy;
- Estimation of ABA and GA in dormant and non-dormant seeds;
- Study on artificial induction of dormancy;
- Dormancy breaking methods – scarification and stratification;
- Dormancy breaking methods – hormonal and chemical treatments;
- Dormancy breaking methods – after ripening and leaching of inhibitors;
- Dormancy breaking methods – combined treatments;
- Assessing the period of natural release of seed dormancy;
- Seed germination – studying the pattern of imbibition;
- Studying the pattern of seed germination in different media;
- Study on influence of light and temperature on germination and seedling development;
- Estimation of hydrolytic enzyme – ? amylase in different species;
- Estimation of hydrolytic enzyme – protease;
- Estimation of hydrolytic enzyme – lipase;
- Estimation of dehydrogenase enzyme and respiratory quotient in seeds;
- Estimation of food reserve composition during seed germination.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignments
- Laboratory experiments
- Group exercises on biochemical estimations

IX. Learning outcome

By learning this course, students will understand the fundamental theories and mechanism underlying in seed dormancy and germination which will be useful for both basic research and development.

X. Suggested Reading

- Baskin C and Baskin JM. 2014. Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination. Academic Press, Cambridge, UK.
- Bewley J and Black M. 1994. Physiology of Development and Germination. Springer, New York. Bewley JD, Bradford KJ, Hilhorst HWM and Nanogaki H. 2013. Seeds: Physiology of
- Development, Germination and Dormancy. Springer, New York.
- Bewley JD and Black M. 1982. Physiology and Biochemistry of Seeds in Relation to Germina tion. Volume 2: Viability, Dormancy and Environmental Control.Springerlink, New York, USA
- Benech-Arnold R and Rodolfo S. 2004. Handbook of Seed Physiology: Applications to agricul ture. CRC Press, Florida, USA.
- Black M and Bewley JD. 2000. Seed Technology and its Biological Basis. CRC Press. Florida, USA.
- Bradbeer JW. 1988. Seed Dormancy and Germination. Chapman and Hall, New York, USA. David R. Murray. 1985. Seed Physiology. Volume 2: Germination and Reserve Mobilisation.
- Academic Press, London, UK.
- Heydecker W. 1985. Seed Ecology. Pennsylvania State University Press, USA.
- Khan AA. 1977. The Physiology and Biochemistry of Seed Dormancy and Germination. North – Holland Publishing Company, USA.
- Kozlowski TT. 2012. Seed Biology: Importance, Development and Germination. (Vol. I). Aca demic Press Inc., New York.
- Maiti RK, Sarkar NC and Singh VP. 2012. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur.
- Maiti RK, Sarkar NC and Singh VP. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.
- Mayer AM and Mayber AP. 1963. Germination of Seeds. Pergamon Press, Oxford, New York. Prakash M. 2011. Seed Physiology of Crops. Satish Serial Publishing house. Azadpur. New Delhi.
- Roberts EH. 1972. Viability of seeds. Springerlink, New York, USA.

XI. Suggested e-books

- https://www.springer.com/in/book/9780792373223
- https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1756-1051.2000.tb01610.X
- https://www.elsevier.com/books/seeds/baskin/978-0-12-416677-6
- https://books.google.co.in/books/about/Physiology_and_Biochemistry_of_ Seeds_in.html?id
- 91nsCAAAQBAJ&printsec=frontcover&source=kp_read_ button&redir_esc=y#v=onepage & q&f=false
- https://books.google.co.in/books/about/The_Germination_of_Seeds.html? id=aV62AgAAQBAJ& printsec=frontcover&source=kp_ read_button&redir_ esc=y#v=onepage&q&f=false
- https://books.google.co.in/books/about/Seed_Dormancy_and_Germination. html?id=18HeBw AAQBAJ&printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false

XII. Suggested websites

- https://agriinfo.in/botany/18/
- https:/sproutnet.com/seed-dormancy/
- https://www.britannica.com/science/germination
- http://www.biologyreference.com/Re-Se/Seed-Germination-and-Dormancy.html
- https://www.intechopen.com/books/advances-in-seed-biology/seed-dormancy

I. Course Title : Seed Production Principles and Techniques in Field Crops

II. Course Code : SST 503

III. Credit Hours : 3 (2+1)

IV. Why this course?

Awareness about the use of quality seed among farmers enhances the seed demand and seed trade. To meet the seed demand, production should be carried out in large areas. Hence, it is essential to learn about the production principles and techniques of quality seed production.

V. Aim of the course

To impart knowledge on principles and practices involved in quality seed production of field crops.

VI. Theory

Unit I

Importance of seed – seed quality concept – factors influencing seed production; generation system of seed multiplication – classes of seed, stages of seed multiplication in varieties and hybrids – seed multiplication ratio (SMR) – seed replacement rate (SRR) – seed renewal period (SRP) – varietal replacement rate (VRR).

Unit II

Genetic and agronomic principles of variety and hybrid seed production; methods and techniques of seed production in varieties and hybrids of important cereals and millets – wheat, oat, rice, maize, sorghum and pearl millet; varietal seed production in small millets – finger millet, fox tail millet, little millet, kodo millet, proso millet and barnyard millet.

Unit III

Methods and techniques of varietal seed production in major pulses – black gram, green gram, cowpea, chickpea, horse gram, soybean and lentil – varietal and hybrid seed production in red gram.

Unit IV

Methods and techniques of seed production in major oil seed crops – groundnut, sesame – varietal and hybrid seed production in sunflower, castor and mustard; varietal seed production in minor oilseed crops (safflower, linseed, niger) – varietal and hybrid seed production in cotton – varietal seed production in jute.

Unit V

Seed production planning for varieties and hybrids of major crops; participatory seed production – seed hubs, seed village concept and community seed bank.

VII. Practical

- Seed selection – quality of seed on field establishment;
- Sowing and nursery management techniques;
- Planting – age of seedling on crop establishment – rice and pearl millet;
- Isolation distance and border rows in hybrid seed production field – space and barrier isolation; modifying isolation based on border rows in maize;
- Planting design for hybrid seed production – rice, maize, pearl millet, cotton, red gram, sunflower;
- Practicing breeding tools for hybrid seed production – detasseling – emasculation and dusting;
- Study on methods of achieving synchronization – rice, bajra, sunflower;
- Practicing supplementary pollination – rice and sunflower;
- Study on foliar nutrition and influence on seed yield;
- Practicing roguing operation – identification of off-types, pollen shedders, shedding tassels, par tials, selfed bolls;
- Pre and post harvest sanitation operations – cereals, millets and pulses;
- Estimation of shattering and shattering loss; study on insitu germination and loss;
- Visit to seed production fields;
- Visit to seed industry;
- Seed production planning and economics of seed production – varieties;
- Seed production planning and economics of seed production – hybrids.

VIII. Teaching methods

- Classroom lectures
- Power point presentation
- Student assignment presentation and group tasks
- Field and laboratory experiments
- Field visits

VIII. Learning outcome

Successful completion of this course enable student to take up seed production venture in scientific manner to ensure seed quality and profitability.

IX. Suggested Reading

- Agrawal RL. 2019. Seed Technology. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi. Hebblethwaite PD. 1980. Seed Production. Butterworth Heinemann Ltd., London, UK.
- Joshi AK and Singh BD. 2004. Seed Science and Technology. Kalyani Publishers, New Delhi.
- Kulkarni GN. 2011. Principles of Seed Technology. Kalyani Publishers, New Delhi.
- Maiti RK, Sarkar NC and Singh VP. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.
- McDonald MB and Copeland L. 1998. Seed Production Principles and Practices. CBS Pub lishers, New Delhi.

- Mondal SS, Saha M and Sengupta K. 2009. Seed Production of Field Crops. New India Publishing Agency, New Delhi.
- Singhal NC. 2003. Hybrid Seed Production in Field Crops. Kalyani Publications, New Delhi. Sen S and Ghosh N. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.
- Singhal NC. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.

X. Suggested e-books

- https://www.springer.com/in/book/9780792373223
- https://www.springer.com/in/book/9780412075513
- https://www.nipabooks.com/info/9788190723763/seed-production-of-field-crops
- https://www.amazon.in/Production-Field-Crops-Brajesh-Tiwari/dp/9380179405
- https://www.cambridge.org/core/journals/journal-of-agricultural-science/article/seed-production- of-agricultural-crops-by-kelly-a-f-227-pages-harlow-longman-1988-price-2500-hard-covers-isbn-0-582-40410-X/8BE3C99DFDC0F02D48E CB53418504D10

XI. Suggested websites

- https://agriinfo.in/botany/18/
- http://www.fao.org/3/a-e8935e.pdf
- http://www.agriquest.info/seed_production.php
- http://agritech.tnau.ac.in/seed_certification/seedtech_index.html
- http://coin.fao.org/coinstatic/cms/media/16/13666518481740/seed_enterprises_ enhacement_ •and_ development_project_in_sierra_leone_mission_1_report_.pdf

I. Course Title : Seed Production: Principles and Techniques in Vegetable Crops

II. Course Code : SST 504

III. Credit Hours : 3 (2+1)

IV. Why this course?

Seed trade is mainly based on high value low volume seeds. Area under vegetable cultivation is increasing day by day, which demands high area under seed production. The thorough knowledge on vegetable seed production will enable the students to take up seed production venture in low volume high value crops.

V. Aim of the course

To impart knowledge on principles and practices involved in quality seed production of vegetable crops.

VI. Theory

Unit I

Importance and present status of vegetable seed industry – factors influencing vegetable seed production; varietal and hybrid seed production techniques in major solanaceous vegetable crops – tomato, brinjal, chilli; malvaceous vegetable crop – seed production techniques of bhendi.

Unit II

Varietal and hybrid seed production techniques in important cucurbitaceous vegetables – gourds and melons, cole crops – cauliflower, cabbage, knol-khol, root vegetables – carrot, beetroot, turnip, radish and other temperate/ hilly vegetable crops.

Unit III

Varietal seed production techniques in major leguminous vegetables – peas and beans; seed production techniques in leafy vegetables – amaranthus, palak, spinach, and lettuce.

Unit IV

Seed production techniques in tuber crops – potato, sweet potato, colocasia, tapioca and yam, seed-plot technique in potato – true potato seed (TPS) production techniques – seed production techniques in bulb crops – onion, garlic.

Unit V

Vegetative and clonal multiplication – methods, merits and demerits; clonal multiplication – potato, sweet potato, colocasia, tapioca and yam.

VII. Practical

- Identification of vegetable seeds;
- Study on sowing and nursery management;
- Study on transplanting and age of seedling on crop establishment;
- Studying floral biology of solanceous, malvaceous and cucurbitaceous vegetable crops;
- Studying floral biology of other vegetable crops;
- Practicing planting design for hybrid seed production;
- Modification of sex ratio in cucurbits;
- Practicing emasculation and pollination methods;
- Practicing roguing operations – identification of off-types – selfed fruits;
- Harvesting methods – single and multiple harvesting method;
- Practicing seed extraction methods – wet methods – tomato, brinjal, other cucurbitaceous fruits;
- Seed extraction – dry methods – chillies, bhendi, cucurbitaceous;
- Visit to seed production fields;
- Visit to private seed industry;
- Planning and economics of varietal seed production;
- Planning and economics of hybrid seed production.

VIII. Teaching methods

- Classroom lectures with power point
- Student assignment and presentations
- Field and laboratory ecperiments
- Demonstration
- Hands on training
- group tasks
- Field and industry visits

VIII. Learning outcome

Successful completion of this course enable student to gain confidence and to become seed entrepreneur in high value low volume vegetable crops.

IX. Suggested Reading

- Agarwal RL. 2012. Seed Technology. OXford & IBH Publishing Company Pvt. Ltd., New Delhi.
- Chadha KL. 1995. Advances in Horticulture. Volume 1 to 13. Malhothra Publishing House,New Delhi.
- George RAT. 1985. Vegetable Seed Production. Lonhman Inc., New York.
- Hebblethwaite PD. 1980. Seed Production. Butterworth Heinemann Ltd, London, UK.
- Kulkarni GN. 2011. Principles of Seed Technology. Kalyani Publishers, New Delhi.
- Maiti RK, Sarkar NC and Singh VP. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.
- McDonald MB and Copeland L. 1998. Seed Production: Principles and Practices. CBS Pub lishers, New Delhi.
- Sen S and Ghosh N. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.
- Singhal NC. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.
- Vanangamudi K, Natarajan N, Srimathi P, Natarajan K, Saravanan T, Bhaskaran M, Bharathi A, Natesan P and Malarkodi K. 2006. Advances in Seed Science and Technology. Vol. 2. Quality Seed Production in Vegetables. Agro bios, Jodhpur.

IX. Suggested e-books

- https://www.springer.com/in/book/9780792373223
- http://203.64.245.61/fulltext-pdf/EB/1900-2000/eb0021.pdf
- http://www.worldseed.org/wp-content/uploads/2017/01/Seed-Production-Good- practice-10.01.17-final.pdf
- https://trove.nla.gov.au/work/6862691?q&sort=holdings+desc&-=1541066209 257&versionId=45008917+251246346

X. Suggested websites

- https://agriinfo.in/botany/18/
- http://agritech.tnau.ac.in/seed_certification/seedtech_index.html
- http://www.yspuniversity.ac.in/vgc/caft/Compendium2017-18.pdf
- https://www.hort.vt.edu/Welbaum/seedproduction/Principles5.html
- http://www.agrimoon.com/wp-content/uploads/Seed-Production-of-Vegetable.pdf
- http://www.ciks.org/downloads/seeds/4.%20Seed%20Production%20Techniques %20for%20 Vegetables.pdf

I. **Course Title : Seed Production Techniques in Fruits, Flowers, Spices, Plantation and Medicinal Crops**

II. **Course Code : SST 505**

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

IV. Why this course?

At present seed industry is expanding towards the low volume and high value seeds. Domestication of fruit, plantation and medicinal plants enable the farmers to cultivate commercially. The seed demands in these crops are increasing day by day. Hence, it is essential to learn the techniques of seed production in fruits, flowers and plantation crops.

V. Aim of the course

To impart comprehensive knowledge on seed production techniques in fruits, flowers, spices, plantation and medicinal crops.

VI. Theory

Unit I

Scope for seed production in fruits, flowers, spices, plantation and medicinal crops; factors influencing seed production and quality; propagation methods – seed and clonal propagation; seed and seedling standards; propagation and seed production techniques in major tropical, sub-tropical and temperate fruit crops; seed orchards – seed collection, extraction processing and storage techniques.

Unit II

Seed production techniques in commercially important flower crops – nursery management, clonal propagation, planting, seed crop management, post-harvest seed handling and storage techniques.

Unit III

Seed production techniques in commercially important seed spices and other spices – nursery management, sowing, seed crop management and post-harvest seed handling and storage techniques.

Unit IV

Seed production in commercially important plantation crops – mother tree selection – criteria – nursery management, elite seedling production, planting, plantation management, post-harvest handling and storage techniques.

Unit V

Methods of quality seed production in commercially important medicinal plants – nursery management, sowing, seed crop management, post-harvest handling and storage methods.

VII. Practical

- Study on the floral biology and pollination mechanism;
- Identification of seeds of fruits, flowers, spices, plantation and medicinal crops;
- Selection of mother plants and trees – phenotypic characters and genotypic characters;
- Study on different types of clonal and vegetative propagules;
- Seed and clonal standards of vegetatively propagating crops;

- Germination improvement treatments for seeds and vegetative propagules;
- Study on selection of planting materials and sowing methods;
- Nursery management practices for elite seedling production;
- Seed extraction methods – wet method and dry method;
- Post harvest seed handling – seed grading, upgrading techniques
- Study of seed storage techniques;
- Practicing seed germination enhancement techniques in fruits, spices and plantation crops;
- Practicing seed germination enhancement techniques in flowers and medicinal crops;
- Planning for seed production – economics of seed production in flower crops;
- Visit to mother tree orchard;
- Visit to plantation and orchard.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentation
- Group exercise
- Field visit

IX. Learning outcome

Successful completion of this course enables the students to take up elite seed and seedling production on commercial scale.

X. Suggested Reading

- Chadha KL. 1995. Advances in Horticulture. (Volume 1 to 13). Malhotra Publishing House, New Delhi.
- Hartman HT and Kester DE. 2000. Plant Propagation: Principles and Practices. Prentice Hall, New Jersey, USA.
- Singh SP. 2001. Seed Production of Commercial Vegetables. Agrotech, New Delhi.
- Vanangamudi K and Natarajan K. 2008. Advances in Seed Science and Technology. Quality
- Seed Production in Spices, Plantation, Medicinal and Aromatic crops (Vol. 5). Agrobios. Jodh pur.
- Vanangamudi KM Prabu and Lakshmi S. 2012. Advances in Seed Science and Technology Vol.
- 7. Flower Seed Production. Agrobios, Jodhpur.

XI. Suggested e-books

- http://www.worldseed.org/wpcontent/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4233836/
- https://www.academia.edu/35629702/Hybrid_Seed_Production_and_Flowers
- http://www.agrimoon.com/horticulture-icar-ecourse-pdf-books/
- https://cbp.icar.gov.in/EBook.aspx

XII. Suggested websites

- www.cimap.res.in/english/index.php

- www.dmapr.org.in/amprs.kau.in/basic-page/publications
- http://ecoursesonline.iasri.res.in/course/view.php?id=153
- http://ecoursesonline.iasri.res.in/course/view.php?id=612
- http://www.celkau.in/Crops/Plantation%20Crops/Rubber/production.aspx
- http://sbc.ucdavis.edu/ Courses/Seed_Production/

I. Course Title : Seed Production Techniques in Forage, Pasture and Green Manure Crops

II. Course Code : SST 506

III. Credits Hours : 2 (1+1)

IV. Why this course?

Agriculture and animal husbandry in India is interwoven and livestock is the source of income when crop failed. To feed the livestock population, cultivation and seed production of fodder and forage crops are much important. Likewise green manure crops maintain soil health, which created heavy demand for quality seed.

Hence, study of seed production techniques in these crops will help to produce quality seeds to meet the growing needs.

V. Aim of the course

To impart knowledge on basic principles and methods of quality seed production in forage and green manure crops.

VI. Theory

Unit I

Scope and importance of seed production in forage, pasture and green manure crops – factors influencing seed production – seasonal influence; problems and constraints in seed production – seed set, shattering and seed dormancy; vegetative and clonal propagules and apomictic seed.

Unit II

Quality seed production techniques in major fodder crops – lucerne, hedge lucerne, leucaena, fodder sorghum, fodder maize and oats.

Unit III

Seed and planting material production techniques of major forage grasses – bajra -napier grass, guinea grass, deenanath grass and *Cenchrus* sp.; forage legumes *Stylosanthus*, cowpea and berseem.

Unit IV

Seed production techniques in major green manure crops – *Glyricidia, Sesbania sp*., sunnhemp, daincha, jute and *Tephrosia sp*.

Unit V

Post-harvest seed handling – processing, threshing, grading and upgrading; dormancy breaking and germination improvement – quality standards for seed and vegetative propagules.

VII. Practical

- Seed collection and identification of seeds;
- Estimation of seed setting and shattering loss;
- Maturity indices – determination of physiological and harvestable maturity;
- Seed extraction and threshing methods;
- Separation of ill filled seeds – practicing different methods;
- Study of seed and clonal materials – standards;
- Quality of planting material and vegetative propagules on crop establishment;
- Seed quality analysis in forage and fodder crops – tiller wise quality analysis;
- Seed quality analysis in determinate and indeterminate crops;
- Study on effect of ratooning on seed quality;
- Practicing seed quality enhancement techniques;
- Practicing different seed extraction and dormancy breaking treatments;
- Preparation of vegetative propagules and planting;
- Planning for seed production in fodder and green manure crops;
- Economics of seed production in fodder, forage crops and green manure crops;
- Visit to forage and fodder seed production farms.

VIII. Teaching Methods

- Classroom teaching
- Power point presentations
- Students assignment and presentation
- Field and laboratory experiments
- Hands on training
- Demonstration
- Field visit

IX. Learning outcome

After completion of course the students gain confidence to start a seed venture on forage and green manure crops.

X. Suggested Reading

- FAO. 2007. Quality Declared Seed System. FAO Plant Production and Protection Publication, FAO, Rome.
- Farity DT and Hampton JC. 1997. Forage Seed Production. Vol. I. Temperate Species. CAB International Publications. UK.
- Froma J. 1997. Temperate Forage Legumes. CAB International Publications. UK.
- Gutterridge RG. 1997. Forage Tree Legumes in Tropical Agriculture. CAB International Publications, UK.
- Masilamani S and Sivasubramanian K. 2016. Seed Production in Green Manures. Kalyani Publications, New Delhi.

XI. Suggested e-books

- https://www.cabi.org/bookshop/book/9780851992143
- https://cgspace.cgiar.org/handle/10568/49375
- http://www.fao.org/docrep/009/a0503e/a0503e00.htm
- http://www.igfri.res.in/pdf/old_bulletins/tropical_pasture.pdf
- https://cgspace.cgiar.org/bitstream/handle/10568/4479/Seed.pdf?sequence= 1&isAllowed=y

XII. Suggested websites

- www.igfri.res.in/
- https://cgspace.cgiar.org/handle/10568/4479
- https://www.euroseeds.eu/grasses-and-clovers
- https://www.sare.org/learning-center/green-manures www.ndri.res.in/ndri/Design/forageres_mag_cen.html
- http://orgprints.org/30588/1/Sort%20Out%20Your%20Soil.pdf

I. Course Title : Seed Legislation and Certification

II. Course Code : SST 507

III. Credit Hours : 3 (2+1)

IV. Why this course?

Awareness on usage of quality seeds among farmers increases the seed demand. To regulate the seed quality and to avoid the spurious seeds in the market, seed legislation and certification procedures should be known by all the stake holders. This course will provide comprehensive knowledge on seed policies, seed law enforcement and seed certification procedures to the learners.

V. Aim of the course

To impart knowledge on seed legislation in relation to seed certification and quality control systems.

VI. Theory

Unit I

Genesis of seed Industry in India; seed quality control – concept and objectives; regulatory mechanisms – Seed Act (1966) – Seed Rules (1968) – statutory bodies – Central Seed Committee – Central Seed Certification Board.

Unit II

Seed Control Order (1983) – New Policy on Seed Development (1988) – EXim Policy – National Seed Policy (2002) – Plant Quarantine Act.

Unit III

Introduction to WTO and IPR – UPOV and its role – OECD seed certification schemes – PPV & FR Act (2001) and Rules (2003) – Seed Bill (2004 and 2011): Seed certification system in SAARC countries, Europe, Canada, Australia and USA.

Unit IV

Seed certification – history and objectives; general and specific crop standards, field and seed standards; seed certification agency – role of certification agency/ department and seed certification officers, phases of seed certification; field inspection – counting procedures – liable for rejection (LFR) – downgrading and partial rejection – reporting.

Unit V

Post-harvest inspection – construction of seed lot number; seed sampling – testing – labeling, sealing and grant of certificate – types and specifications for tags and labels; seed lot validity and revalidation; appellate authority, stop sale order, penalties records and registers to be maintained by seed processing units and seed dealers – verification procedures, role of seed analyst and seed inspector in quality regulation.

VII. Practical

- Preparation of sowing report – varieties – transplanted and direct sown crops and hybrids;
- Verification of sowing report – seed certification procedures;
- Field inspection – estimation of area and isolation distance, stages of inspection for varieties and hybrids – procedures;
- Practicing field counting procedures – methods for row planting, broadcasted – varieties;
- Practicing field counting procedures – direct sown and transplanted crops – varieties;
- Study on field counting procedures – hybrids – planting design, planting ratio and block method and double count;
- Identification of contaminants – genetic and physical contaminants, procedure to remove partials, pollen shedders and shedding tassels;
- Assessing and calculation of field standards for important crops;
- LFR, partial rejection and downgrading – reasons, procedures and preparation of reports;
- Yield estimation – single and multiple harvest crops;
- Post harvest inspection – groundnut, cotton, pulses;
- Inspection and maintenance (licence and renewal) of records in processing unit – float test, preparation of processing report and seed lot number construction;
- Visit to seed certification agency/ department;
- Visit to grow-out test field;
- Visit to seed retail shop – procedures followed by Seed Inspector, verification of records and reporting;
- Procedure to issue tag, specification, bagging, tagging, labelling and sealing.

VIII. Teaching methods

- Classroom lectures
- Guest lectures
- Student assignments and presentations
- Demonstrations
- Field visits

IX. Learning outcome

This course will be useful to develop human resource on seed certification and legislation. Successful completion of this course enables students to become a Seed Certification Officer and Seed Inspector.

X. Suggested Reading

- Agarwal RL. 2012. Seed Technology. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi. Anon. 2016. Manual of Seed Certification Procedures. Directorate of Seed Certification, Coimbatore, Tamil Nadu.
- Chakrabarthi SK. 2010. Seed Production and Quality Control. Kalyani Publishers, New Delhi.
- Mishra DK, Khare D, Bhale MS and Koutu GK. 2011. Handbook of Seed Certification. Agrobios, Jodhpur, Rajasthan.
- Neema NP. 1986. Principles of Seed Certification and Testing. Allied Publishers, New Delhi
- Ramamoorthy K, Sivasubramaniam K and Kannan M. 2006. Seed Legislation in India. Agrobios,
- Jodhpur, Rajasthan.
- Renugadevi J, Srimathi P, Renganayaki PR and Manonmani V. 2012. A Handbook of Seed Testing. Agrobios, Jodhpur, Rajasthan.
- Sharma P. 2008. Seed Legislation. Gene-tech Book Publishers, New Delhi.
- Trivedi PC. 2011. Seed Technology and Quality Control. Pointer Publications, Jaipur, Rajasthan.
- Tunwar NS and Singh SV. 2003. Indian Minimum Seed Certification Standards. Central Seed Certification Board, Ministry of Agriculture, GOI, New Delhi.

XI. Suggested e-books

- http://cms.tn.gov.in/sites/default/files/documents/seed-certification-0.pdf
- http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material/INDIAN-MINIMUM-SEED-CERTIFICATION-STANDARDS.pdf
- https://www.india.gov.in/my-government/documents/e-books
- https://books.google.co.in/books/about/Principles_of_Seed_Certification_and_ Tes.html?id= SQWHAAAACAAJ&redir_esc=y
- https://dl.sciencesocieties.org/publications/books/tocs/cssaspecialpubl/theroleofseedce

XII. Suggested websites

- www.fao.org www.agri.nic.in
- www.agricoop.nic.in
- www.gov.mb.ca
- http:/agritech.tnau.ac.in
- www.betterseed.org
- www.oecd.org/india/
- http://www.tnagrisnet.tn.gov.in/
- https://pir.sa.gov.au/_data/assets/pdf_file/0003/148134/SeedCertification Manual.pdf

I. Course Title : Post Harvest Handling and Storage of Seeds

II. Course Code : SST 508

III. Credit Hours : 3 (2+1)

IV. Why this course?

Healthy seeds are the demanding enterprise of the recent era for the production of high yield in the next season. The seeds must be well processed and stored for the maintenance of high-yielding crop. During storage, major losses of seeds are caused by various biotic and abiotic factors. There is a need apply proper post harvest handling and storage techniques, which ultimately improve the market value and quality of the seed.

V. Aim of the course

To impart knowledge on principles, techniques and methods of seed processing, treatment and storage.

VI. Theory

Unit I

Seed processing – objectives and principles; processing sequence – threshing, shelling, ginning, extraction methods; drying – principles and methods; seed cleaning, grading, upgrading – methods – machineries and equipment – scalper, pre-cleaner, cleaner cum grader, specific gravity separator, indented cylinder, disc separator, spiral separator, velvet separator, magnetic separator, electronic colour sorter – working principles and functions.

Unit II

Online seed processing – elevators and conveyers – processing plant – specifications, design and layout; mechanical injury – causes and detection – management.

Unit III

Seed treatment – methods – pre and mid storage seed treatments, seed treating formulations and equipments; packaging materials – types – bagging and labeling; seed blending – principle and methods.

Unit IV

Seed storage – purpose and importance – factors affecting storage, optimum condition for storage of different seeds; storage principles – Harrington's thumb rule – concepts and significance of moisture equilibrium – maintenance of safe seed moisture – physical, physiological, biochemical and molecular changes during seed storage – storage behaviour of orthodox and recalcitrant seeds – prediction of viability – viability nomograph.

Unit V

Methods of seed storage – modified atmospheric storage – ultra dry storage – vacuum storage – cryopreservation – germplasm storage – gene banks – NBPGR, IPGRI and National seed storage laboratory; seed storage godown – structure – maintenance – sanitation.

VII. Practical

- Seed extraction – wet and dry methods;
- Seed processing sequence for different crops;
- Design of processing plant – equipments – estimation of processing efficiency;
- Seed drying methods – principle and methods;
- Practicing seed grading – upgrading techniques;
- Delinting methods – assessment of mechanical damage;
- Visit to seed processing unit;
- Seed packaging – effect of packaging materials on seed longevity;
- Prediction of viability during storage – viability nomograph and accelerated ageing test;
- Assessing physical changes during seed storage;
- Assessing physiological changes during seed storage;
- Assessing biochemical changes during seed storage;
- Storage behaviour of recalcitrant seeds;
- Pre-storage seed treatments – protectants – antioxidants – halogens;
- Practicing seed blending methods;
- Seed storage godown – sanitation, fumigation – visit to seed storage godown and cold storage unit.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignment and presentation
- Processing experiments
- Demonstration
- Hands on training
- Exposure and field visits

IX. Learning outcome

The students will understand the principles and mechanism involved in seed processing, storage techniques and management practices to arrest the seed deterioration. Students will also acquire skill on seed handling and storage methods on commercial basis.

XI. Suggested Reading

- Barton LV. 1961. Seed Preservation and Longevity, (Vol. 1). Leonard Hill, London.
- Gregg BR, Law AG, Virdi SS and Balis JS. 1970. Seed Processing. Avion printers, New Delhi.
- Gupta D. 2009. Seeds: their conservation principles and practices. Sathish serial publishing house. New Delhi.
- Justice OL and Bass LN. 1978. Principles and Practices of Seed Storage. Agriculture Hand Book No. 506, Castle House Publication Ltd., Washington.
- Kulkarni GN. 2011. Principles of Seed Technology. Kalyani Publishers, New Delhi.
- Maiti RK, Sarkar NC and Singh VP. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.

- Padmavathi S, Prakash M, Ezhil Kumar S, Sathiyanarayanan G and Kamaraj A. 2012. A Text book of Seed Science and Technology, New India Publishing Agency, New Delhi.
- Sen S and Ghosh N. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi. Singhal NC. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.

XI. Suggested e-books

- http://dfsc.dk/pdf/Handbook/chapter8_internet.pdf
- https://naldc.nal.usda.gov/download/CAT87208646/PDF
- https://www.springer.com/in/book/9780792373223
- http://203.64.245.61/ fulltext-pdf/EB/1900-2000/eb0021.pdf
- https://www.kopykitab.com/ebooks/2016/05/6997/sample/sample_6997.pdf
- https://trove.nla.gov.au/work/6862691?q&sort=holdings+desc&-=1541066209257 &versionId= 45008917+251246346
- http://www.worldseed.org/wp-content/uploads/2017/01/Seed-Production-Good-practice-10.01.17- final.pdf

XII. Suggested websites

- http://www.fao.org/3/a-ah803e.pdf
- agritech.tnau.ac.in/seed_certification/seedtech_index.html
- http://ecoursesonline.iasri.res.in/mod/page/view.php?id=17806
- http://www.bcseeds.org/wp-content/uploads/2015/01/Seed-Processing-2015-update.pdf
- https://www.carolinafarmstewards.org/wpcontent/uploads/2012/05/Seed Processingand StorageVer_1pt3.pdf

I. Course Title : Seed Quality Testing and Enhancement

II. Course Code : SST 509

III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed is the basic input in agriculture and the productivity is mainly depends on field population of plants. By sowing quality seeds, population can be maintained. Hence, it is necessary to know the quality parameters to be analyzed. Through seed treatments, the performance of seed can be improved. Especially to address the drought and climate change the knowledge on seed enhancement techniques is much essential.

V. Aim of the course

To impart knowledge on principles, techniques and methods of seed testing and seed quality enhancement.

VI. Theory

Unit I

Seed testing – history and development; seed testing in India; ISTA and its role in seed testing; seed lot and size, types of seed and size, samples – sampling – intensity and methods, sampling devices, receipt and registration of submitted samples in the laboratory and sub sampling; purity analysis – components and procedure – determination of other distinguishable varieties (ODV) and test weight determination – application of heterogeneity test – method of testing coated and pelleted seeds; seed moisture estimation – principles and methods, application of tolerances.

Unit II

Seed germination test – requirements, media and methods – seedling evaluation, tolerance and reporting results; viability test (TZ test) – principle, procedure and evaluation; vigour tests – concept of seed vigour and vigour test – types of vigour tests – direct and indirect tests – physical, physiological and biochemical tests – principles and methods; seed health test – principles and methods.

Unit III

Genetic purity assessment – laboratory methods – physical, chemical, biochemical and molecular tests – growth chamber and field testing (Grow Out Test) methods; testing of GM seeds; storage of guard sample – referral test; application of tolerance in seed testing; advanced non destructive techniques of seed quality analysis – soft x-ray imaging – hyper spectral imaging, thermal imaging – spectroscopy – e-nose and machine vision techniques.

Unit IV

Seed quality enhancement techniques – history and development; classification – physical, physiological and protective seed treatments – special seed treatments; physical seed treatment – liquid floatation, specific gravity separation, irradiation, electric and electro-magnetic seed treatments – principles and methods – seed pelleting and coating principles, purpose and methods.

Unit V

Physiological seed enhancement treatments – seed infusion, seed priming – principles and methods – physiological, biochemical and molecular mechanisms; pre-germination and fluid drilling techniques; biological seed treatments – microbial inoculation; organic seed treatment – integrated seed treatment – concept and methods of designer seed.

VII. Practical

- Seed testing – sampling and dividing methods;
- Determination of seed test weight and heterogeneity test;
- Physical purity analysis – components, procedure, reporting results;
- Seed moisture estimation – methods and equipments;
- Conduct of seed germination test and seedling evaluation;
- Conduct of quick viability (tetrazolium) test and evaluation;
- Conduct of vigour tests – direct, indirect test and special tests;
- Genetic purity assessment – laboratory and conventional methods – image analysis for seed quality;
- Conducting different seed health tests to identify bacteria, fungi and insects;
- Visit to seed testing laboratory;
- Seed enhancement techniques – practicing physical treatments and water floatation techniques;
- Seed coating and pelleting – uses of adhesives and filler materials;
- Performing seed priming – hydro, halo and bio-priming – solid matrix priming;
- Practicing seed infusion and microbial inoculation treatments;
- Practicing pre-germination technique;
- Studying integrated seed treatment/ designer seed treatment.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentations
- Laboratory experiments
- Demonstration
- Hands on training
- Exposure visits

IX. Learning outcome

Successful completion of this course by the students will be useful to acquire technical skill on seed quality analysis which leads to the development of human resource on seed quality analysis.

X. Suggested Reading

- Agrawal PK. 1993. Hand book of Seed Testing. Ministry of Agriculture, GOI, New Delhi Agrawal RL. 1997. Seed Technology. Oxford & IBH.
- Agrawal PK and Dadlani M. 1992. Techniques in Seed Science and Technology. 2nd Ed. South Asian Publications.
- Chakrabarthi SK. 2010. Seed Production and Quality Control. Kalyani Publishers. New Delhi. Chalam GV Singh A and Douglas JE. 1967. Seed Testing Manual. ICAR and United States
- Agency for International Development, New Delhi.
- Copeland LO and McDonald MB. 2001. Principles of Seed Science and Technology. 4th Ed. Kluwer Academic publishers, USA.
- International Seed Testing Association. 2018. Handbook on Seedling Evaluation, 4th Edition, Published by ISTA, Zurichstr, Switzerland.
- International Seed Testing Association. 2019. International Rules for Seed Testing 2019. Pub lished by ISTA, Zurichstr, Switzerland.
- ISTA. 1999. Seed Science and Technology, 27th supplement.
- Renugadevi J, Srimathi P, Renganayaki PR and Manonmani V. 2012. A Hand book of Seed Testing. Agrobios. Jodhpur, Rajasthan.
- Tridevi PC. 2011. Seed Technology and Quality Control. Pointer Publication. Jaipur, Rajasthan.
- Vasudevan SN, Doddagowder SR, Rakesh CM and Patil SB. 2013. Seed Testing and Quality Control. Agrotech Publications, Udaipur, Rajasthan.

XI. Suggested e-books

- http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material/INDIAN MINIMUM SEED CERTIFICATION STANDARDS.pdf.
- www.kopykitab.com/Seed-Testing-and-Quality-Control-by-Vasudevan-SN
- https://www.jstor.org/stable/10.14321/j.ctt7zt51m
- https://link.springer.com/chapter/10.1007/978-1-4615-1619-4_13
- https://www.researchgate.net/publication/269694458_QUALITY_SEED_ PRODUCTION_ITS_ TESTING_AND_CERTIFICATION_STANDARD
- https://www.seedtest.org/upload/cms/user/ISTAMethodValidationforSeed Testing-V1.01.pdf
- https://www.intechopen.com/books/new-challenges-in-seed-biology-basic-and-translational- re search-driving-seed-technology/recent-advances-in-seed-enhancements

XII. Suggested websites

- http://agritech.tnau.ac.in/seed/Seed_seedtesting.html
- https://core.ac.uk/download/pdf/85210907.pdf
- https://www.betterseed.org/resources/seed-testing-accreditation-schemes/
- http://sbc.ucdavis.edu/About_US/Seed_Biotechnologies/Seed_Enhancement/
- https://www.seedtest.org/en/international-rules-for-seed-testing-content-1-1083. html

I. Course Title : Seed Technology of Tree Species

II. Course Code : SST 510

III. Credit Hours : 2 (1+1)

IV. Why this course?

Tree seed production is an important primary niche for carrying forward sustainable agriculture and forest resource management. Knowledge of the seed biology of a tree species is essential to successful seed production and handling of tree crops. The sexual life cycle must be known to plan for genetic improvement, production, collection, conditioning, storage and planting of the seeds for propagation of trees.

V. Aim of the course

To make the students gain knowledge on seed production and handling techniques of various tree species.

VI. Theory

Unit I

Importance of tree seeds – seed quality in plantation establishment – scope of seed production in tree species; seed structure and its significance in natural regeneration of forest species.

Unit II

Reproductive biology – angiosperms and gymnosperms – reproductive age – seasonal influence on flowering – reproductive efficiency; factors influencing seed set – pollination – pollinating agents – self incompatibility – seed dispersal – mode and mechanism of dispersal.

Unit III

Seed stand – selection and delineation – seed production area – seed zone – selection criteria for candidate, plus and elite tree; seed orchards – definition – types – seedling and clonal seed orchard – pollen dilution zone – seed orchard establishment and management; OECD certification programmes for forest reproductive materials and seeds – ISTA certification standards for tree species.

Unit IV

Physiological maturity – maturity indices – determining optimum harvestable maturity; seed collection – methods – factors influencing seed collection – precautions in collection of recalcitrant seeds; seed extraction – methods – wet, dry and cone extraction; drying – critical moisture content – seed processing; dormancy – types of dormancy in tropical, sub tropical and temperate tree seeds – dormancy breaking treatments; recalcitrant seeds – mechanism.

Unit V

Seed production and handling techniques in important tree borne oil seeds (Madhuca, Pongamia, Azadirachta, Simaruba, Callophyllum), timber (teak, sandal, pine, cedar, red sanders, shisham), fuel wood (Acacias), pulp wood (Bambusa, Ailanthus, Casuarina, Melia, Eucalyptus), fodder (Leucaena, Albizzia) and ornamental (Cassia, Delonix) tree species.

VII. Practical

- Study of tree seed structure – internal and external structures;
- Study on phenology of different tree species;
- Selection procedure of candidate and plus trees;
- Assessment of seed set, physiological and harvestable maturity;
- Assessing natural regeneration in different tree species;
- Study on seed dispersal methods and dispersal distance in different species;
- Seed collection techniques in important tree species – seed collection – orthodox and recalcitrant Seeds – safety measures during collection;
- Seed extraction methods – wet and dry extractions – fruits, pods, cones, etc.;
- Study on different seed drying methods and precautions;
- Practicing seed grading and upgrading techniques;
- Practicing seed dormancy breaking methods;
- Germination improvement treatments for elite seedling production;
- Study on storage of recalcitrant seed;
- Estimation of critical moisture content for safe storage;
- Visit to seed production area and seed orchard;
- Visit to tree seed processing unit.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignments and presentation
- Group exercise
- Laboratory experiments
- Field visit to seed orchard

IX. Learning outcome

Knowledge of the seed biology of a tree species enable to produce good quality seeds, handling and prevent loss of seeds. The knowledge on sexual life cycle enables them to plan for genetic improvement, production, collection, conditioning, storage, and planting of the seeds.

X. Suggested Reading

- Dennis AJ, Schepp EN, Green RJ and West cott DA. 2007. Seed Dispersal. Agrobios, Jodhpur.
- Khanna S. 1993. Principles and Practices of Silviculture. Khanna Bandhu, Dehradun, India.
- Lars Schmidt 2000. Guide to Handling of Tropical and Sub Tropical Forest Seed. Danida Forest Seed Centre, Denmark.

- Negi SS. 1998. Forest Tree Seed. International Book Distributors, Dehradun, India.
- Ram Prasad and Khandya AK. 1992. Handling of Forestry Seeds in India. Associated Publish ers, New Delhi.
- Sivasubramaniam K, Raja K and Geetha R. 2012. Recalcitrant Seeds – Causes and Effects. Sathish Serial Publishing House. Azadpur, New Delhi.
- Umarani R and Vanangamudi K. 2004. An Introduction to Tree Seed Technology. International Book Distributors, Dehradun.
- Vanangamudi K, Natarajan K, Saravanan J, Natarajan N, Umarani R, Bharathi A and Srimathi P. 2007. Advances in Seed Science and Technology: Forest Tree Seed Production (Vol. 4). Agrobios, Jodhpur
- Willan RL. 1985. A guide to Forest Seed Handling. FAO, Rome
- Zoebel B and Talbert TT. 1984. Applied forest tree improvement. Joh willey and Sons, New Yark.

XI. Suggested e-books

- http://www.fao.org/3/a-ah803e.pdf
- http://www.fao.org/3/ad232e/AD232E01.htm
- https://www.springer.com/gp/book/9783540490289
- http://www.fao.org/docrep/006/ad232e/ad232e00.htm
- http://envis.nic.in/ifgtb/pdfs/Tree%20Seed%20Management.pdf
- https://www.forestry.gov.uk/PDF/FCBU054.pdf/$FILE/FCBU054.pdf
- https://www.forestry.gov.uk/PDF/FCBU059.pdf/$FILE/FCBU059.pdf

XII. Suggested websites

- www.ista.org.in ifgtb.icfre.org/index.php
- http://www.kfri.res.in/research.asp
- http://www.fao.org/3/ad232e/AD232E21.htm
- https://www.srs.fs.usda.gov/pubs/gtr/gtr_so107.pdf
- http://www.sfri.nic.in/pdf_files/Seed%20Technology.pdf

I. Course Title : Seed Industry and Marketing Management

II. Course Code : SST 511

III. Credit Hours : 2 (1+1)

IV. Why this course?

India has a vibrant seed market. Over the years, the seed industry has evolved side by side with Indian agriculture. Indian seed industry is the fifth largest seed market in the world. This course will provide insights in seed industry development and better management of seed industry and seed marketing.

V. Aim of the course

To empower the students to become seed entrepreneurs by imparting knowledge on seed industry management and marketing strategies.

VI. Theory

Unit I

Introduction to seed industry – genesis, growth and structure of seed industry – mission and objectives – present status of Indian and global seed industry – role of seed industry in Indian agriculture; government initiatives – seed hubs, seed villages and community seed production system.

Unit II

Seed industry – organization set up and functions – public, private, MNC's, seed corporations; structure of small, medium and large seed industries, components of seed industry – public private partnership – custom seed production – risk management – human resource – infrastructure – processing unit – storage go down.

Unit III

Seed production and distribution systems in state and central government; seed supply chain systems – seed production and distribution – planning, organization and coordination, staffing, assembling of resources; cost of seed production – overhead charges.

Unit IV

Seed marketing – definition – importance – role of marketing; type of markets – domestic and global market – problems and perspectives; marketing policies – seed marketing schemes – marketing channels, responsibilities of dealers – marketing mix.

Unit V

Seed demand forecasting – purpose – methods and techniques; indenting and seed dispatch procedures and forms – seed store records – maintenance – missing link in seed supply chain; market intelligence – SWOT analysis; seed cost analysis; seed pricing – policy – components of seed pricing – factors – local market rate (LMR) – fixation of procurement and sale price of seed.

VII. Practical

- Data collection on status of Indian and global seed industry;
- Assessing the factors influencing farmers preference and assessment of seed demand and supply;
- Planning for establishment of small, medium and large seed industry;
- Planning for establishment of seed production and processing unit;
- Economics of seed production – varieties and hybrids;
- Seed pricings and cost analysis;
- Exercise on fixing seed procurement and sale price;
- Study of marketing channels – domestic and international;
- Maintenance of carryover seeds – Assessing risk factors in seed industry and their management;
- Survey and interaction with seed dealers and distributors;
- Visit to state seed corporations;
- Visit to MNCs and expert discussion;
- Case studies and SWOT analysis;
- Visit to modern seed processing unit and advanced seed storage complex;
- Custom seed production, contract farming and procurement – procedures;

- Planning and preparation of project proposal for setup of a seed industry;
- Final practical examination.

VIII. Teaching methods

- Classroom lectures
- Survey
- Student assignment and presentation
- Economic analysis
- Group discussion
- Swot analysis
- Seed industry visit and interaction sessions

IX. Learning outcome

On completion of this course students will gain knowledge and confidence to manage seed industry and able to address the problems in seed industry and seed marketing.

X. Suggested Reading

- Acharya SS and Agarwal NL. 2004. Agricultural Marketing in India. 4th Ed. Oxford and IBH. Broadway AC and Broadway A. 2003. A Text Book of Agri-business Management.
- Kalyani Singh AK and Pandey S. 2005. Rural Marketing. New Age Publications. Kugbei S. 2008. Seed Economics. Scientific Publishers, Jodhpur, Rajasthan.
- Sharma P. 2008. Marketing of Seeds, Green-Tech Book Publishers, New Delhi.
- Singh G and Asokan SR. 1991. Seed Industry in India: A Management Perspective Oxford & IBH Publishing Co Pvt. Ltd., New Delhi.
- Singh S. 2004. Rural Marketing – Focus on agricultural Inputs. Vikas Publishing House.

XI. Suggested e-books

- https://link.springer.com/chapter/10.1007/978-1-4615-1783-2-15
- http://www.fao.org/3/V4450E/V4450E00.htm
- https://books.google.co.in/books?id=vPVlBos4WkYC
- http://download.nos.org/srsec319new/319EL19.pdf
- https://isengewant.de/Marketing-of-Seeds-By-Premjit-Sharma.pdf
- https://www.kopykitab.com/A-Handbook-of-Seed-Processing-and-Marketing-by- Gaur-SC Agarwal R

XII. Suggested websites

- www.gov.mb.ca
- www.agricoop.nic.in www.agri.nic.in
- https://sathguru.com/seed/
- http://www.fao.org/3/V4450E/V4450E03.htm
- https://www.seednet.gov.in/smis/SMIS-User%20Manual.pdf
- https://www.icrisat.org/seed-systems-models-lessons-learned/
- https://www.bookdepository.com/Seed-Industry-India-Gurdev-Singh/

I. Course Title : Seed Health Testing and Management

II. Course Code : SST 512

III. Credit Hours : 2 (1+1)

IV. Why this course?

Seeds are the foundation for crop production and seed health is related to food production in many ways. Healthy seeds, free from seed transmitted pathogens, are a prerequisite for sustainable food production. Seeds are routinely tested to prevent and control plant pests and pathogens that may affect seed quality, seed movement when introduced into new territories. A seed health test is also frequently a phyto-sanitary requirement imposed by national plant protection authorities. This course aids in timely detection and management of seed borne pest and diseases and supply of pest and disease free seeds in market.

V. Aim of the course

To acquaint the students with principle and practices of seed health testing and management of seed borne pathogens and storage insects.

VI. Theory

Unit I

History and economic importance of seed health in seed industry and plant quarantine – important seed borne and seed transmitted pathogens – role of microorganisms in seed quality deterioration – storage and field fungi – effect of storage fungi on seeds – factors influencing storage fungi and management.

Unit II

Transmission of pathogens – mode and mechanism – seed certification standards; mycotoxins – types and its impact on plant, animal and human health; seed health testing methods – direct examination, incubation, serological and molecular methods.

Unit III

Production of disease free seeds in agricultural and horticultural crops; management of seed borne pathogens – plant quarantine – Indian system and networking, post- entry quarantine and international systems – Pest Risk Analysis (PRA); Sanitary and Phytosanitary System (SPS) – certificates; International Seed Health Initiative (ISHI) on seed health standards.

Unit IV

Storage pests – insects, mites, rodents and their development – economic importance; insect infestation – factors influencing, sources and kinds, biochemical changes in stored seeds due to insect infestation; detection methods and estimation of storage losses; types of seed storage structures – domestic and commercial.

Unit V

Fumigation – principles and techniques – type of fumigants; preservatives and seed protectants on seed quality – non-chemical methods for managing seed storage pests – controlled and modified atmospheric storage – trapping devices – IPM for seed storage.

VII. Practical

- Detection of seed borne pathogens – direct examination;
- Detection of seed borne pathogens – incubation methods;
- Detection of seed borne pathogens – serological methods;
- Detection of seed borne pathogens – molecular methods;
- Study on seed transmission of seed borne fungi, bacteria and viruses;
- Identification of storage fungi;
- Management of seed borne pathogens – seed treatment methods;
- Identification of storage insects – internal and external feeders influencing insects;
- Study on the effect of pre harvest spray on field carryover storage pests;
- Estimation of storage losses due to pests;
- Methods of detection of insect infestation;
- Management of storage pests – pesticides, dose determination, preparation of solution and application;
- Management of storage pests – non-chemical management methods;
- Demonstration of controlled atmospheric storage;
- Safe handling and use of fumigants and insecticides;
- Visit to seed storage godowns.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignment and presentation
- Laboratory experiments
- Hands on training.

IX. Learning outcome

Successful completion of this course will provide knowledge on production of healthy seeds by timely detection and management of seed borne pathogens and storage pests to meet phyto-sanitary requirements.

X. Suggested Reading

- Agarwal VK and Sinclair JB. 1996. Principles of Seed Pathology. Edition, CRC Press Inc. Boca Raton, FL.
- Athanassiou CG and Arthur FH. 2018. Recent advances in stored product protection. Springer-Verlag, Germany
- Cotton, RT. 2007. Insect Pests of Stored grain and Grain products. Burgess Publ. Co., Minneopolis, Minn., USA
- Karuna V. 2007. Seed Health Testing. Kalyani Publishers, New Delhi.
- Karuna V. 2009. Fundamentals of Seed Pathology. Kalyani Publishers, New Delhi.
- Neergaard P. 1979. Seed Pathology. Vol. 1. The Macmillan Press Ltd.
- Ranjeet K. 2017. Insect Pests of Stored grain – Biology, Behaviour and Management Strategies. Apple Academic Press, New York, USA.

XI. Suggested e-books

- https://link.springer.com/book/10.1007/978-1-349-02842-9
- https://www.crcpress.com/Principles-of-Seed-Pathology/Agarwal-Sinclair/p/book/9780429152856
- https://books.google.co.in/books/about/Seed_Pathology.html?id=lvVJAAAAYAAJ &redir_esc=y
- https://www.taylorfrancis.com/books/9781315365695
- https://www.ebooks.com/en-us/610606/insects-of-stored-products/david-rees/
- https://www.elsevier.com/books/insects-and-seed-collection-storage-testing-and-certification/kozlowski/978-0-12-395605-7

XII. Suggested websites

- www.tnagrisnet.tn.gov.in/ www.storedgrain.com.au/
- https://openlibrary.org/subjects/seed_pathology
- http://ciat-library.ciat.cgiar.org/articulos_ciat/2015/12620.pdf www.grainscanada.gc.ca/en/
- https://entomology.ca.uky.edu/ef145 http://www.fao.org/3/t1838e/T1838E00.htm#Contents
- https://www.agric.wa.gov.au/pest-insects/insect-pests-stored-grain

SERICULTURE

Course Title with Credit Load

M.Sc. (Agri) in Sericulture

Course Code	Course Title	Credit Hours
	Major courses	
SER 501	Mulberry Production Technology	2(1+1)
SER 502	Genetics and Breeding of Mulberry	2(1+1)
SER 506	Systematics and Morphology of Sericigenous insects	2(1+1)
SER 509	Silkworm Egg Production Technology	2(1+1)
SER 510	Silkworm Rearing Technology	2(1+1)
SER 511	Genetics and Breeding of Silkworms	2(1+1)
SER 512	Diseases and Pests of Silkworms	2(1+1)
SER 514	Silk Technology-I	2(1+1)
SER 515	Non-mulberry Sericulture	2(1+1)

Course Contents
M.Sc. (Agri) in Sericulture

I. Course Title : Mulberry Production Technology

II. Course Code : SER 501

III. Credit Hours : 2(1+1)

IV. Why this course ?

Mulberry is a perennial deep-rooted high biomass producing foliage crop, cultivated as a sole food for silkworm (Bombyx mori L). Mulberry cultivation is the very foundation of commercial sericulture to raise a successful cocoon crop. The quantity of leaf produced and its quality has a direct bearing on silkworm health and the quantity of cocoons produced. Thus, the profitability of sericulture and quality of cocoons depends on nutritive quality of mulberry leaves, as nearly as 70% of the silk proteins produced by the silk-worm are directly derived from the mulberry leaves in addition to other nutrients. Hence, cultivation and best yield of the mulberry plants occupy important place in sericulture.

V. Aim of the course

The course is designed to provide both theory and practical knowledge on scope of mulberry sericulture, global distribution and factors influencing mulberry leaf yield and quality. Mulberry varieties, selection of site for garden, propagation techniques, soil and climatic requirements will be taught. Package of practices for raising mulberry saplings, rainfed and irrigated mulberry cultivation, separate chawki garden, tree mulberry, mulberry cultivation in hilly areas, intercropping, organic farming and IFS component will be part of the course. Use of growth hormones and growth regulators on mulberry leaf yield and quality will be studied in addition to pests and diseases of mulberry. Mulberry farm management and economics of mulberry production will e added.

The course is organized as follows:

No.	Blocks	Units	
1	Introduction, scope and varieties	I.	Overview and scope of mulberry sericulture
		II.	Varieties of mulberry
2	Mulberry production	I.	Raising of mulberry saplings and planting.
		II.	Establishment of mulberry garden
3	Mulberry protection	I.	Mulberry pests and their management
		II.	Mulberry diseases and their management
4	Economics	I.	Economic of mulberry production]

VI. Theory

BLOCK 1: Introduction, scope and varieties

Unit I: Overview and Scope of mulberry sericulture

Scope of mulberry sericulture, an overview of sericulture industry in the world and India. Leaf quality requirements, factors influencing mulberry leaf yield and quality. Scope for mechanization in mulberry cultivation.

Unit II: Varieties of mulberry

Mulberry varieties, Traditional mulberry varieties, popular mulberry varieties in different climatic zones, high yielding varieties, varieties for rainfed condition, varieties for specific conditions.

BLOCK 2: Mulberry production

Unit I:Raising of mulberry saplings and planting

Technology for raising of saplings for bush and tree type mulberry cultivation. Preparation of bed, planting material, transportation, storage, planting, weeding, fertilizer application and disease and pest management, uprooting, transportation and planting in main field.

Unit II: Establishment of mulberry garden

Package of practices for rainfed and irrigated mulberry cultivation, separate chawki garden, tree mulberry, mulberry cultivation in hilly areas. Selection of land, land preparation, planting, initial care and maintenance for different methods of mulberry cultivation and pruning practices. Mechanization in mulberry cultivation, intercropping, organic farming and IFS component. Manure and fertilizer schedule, irrigation schedule, use of biofertilizers for enhanced yield, use of growth hormones and growth regulators.

BLOCK 3: Mulberry protection

Unit I : Mulberry pests and their management

Mulberry pest status, occurrence, type of damage, symptoms, crop loss, life-cycle, different methods of management techniques, Integrated Pest Management (IPM) in mulberry.

UnitII : Mulberry diseases and their management

Mulberry diseases, occurrence, damage, symptoms, crop loss and different methods of management techniques and Integrated Disease Management (IDM) in mulberry.

BLOCK 4: Economics

Unit I : Economic of mulberry production

Farm records, role of non-monetary inputs in mulberry production, effective farm management, economics of mulberry production.

VII. Practicals

- Analysis of area, production and productivity of mulberry and sericulture in Karnataka, India and world;
- Study of Agronomic features of different mulberry varieties;
- Practising of different mulberry planting systems;
- Study of rooting and sprouting behaviour of mulberry varieties;
- Raising saplings through soft, semi soft and apical tender shoots;
- Mulberry nursery establishment and management;
- Study of mulberry as an intercrop in plantations;
- Selection of fruits and preparation of mulberry seeds for raising mulberry seedlings;
- Study of different planting systems of tree mulberry;
- Study of Intercropping in mulberry garden;
- Study of organic mulberry farming;
- Study of Mulberry as IFS component;
- Effect of different pruning systems on mulberry yield;
- Estimation of leaf area by non-destructive and destructive methods;

- Study of different leaf preservation techniques and different methods of leaf harvest with special reference to chawki and grown up silkworms;
- Study of different schedules of operation in mulberry garden and fertilizer application, methods of application and irrigation schedules;
- Study of weed flora in mulberry garden;
- Study of Farm records and Economics of mulberry cultivation;
- Institutional/ Farmers field visits.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books\
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

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

- Appreciate the scientific foundation of mulberry cultivation and relate the key learning to both research and extension
- Utilise methods and tools for mulberry nursery and mulberry production
- Utilise material in scientific publications relevant to mulberry production technology and adoption that critically reflect on their benefits.

X. Suggested Reading

- Anonymous. 1975. Textbook of Tropical Sericulture. Japan Overseas Co-operation volunteers, Japan, p.594.
- Aruga H. 1994. Principles of Sericulture. OXford & IBH, New Delhi, p. 376.
- Dandin SB, Jaiswal and Giridhar. 2003. Handbook of Sericulture Technologies. CSB, Bangalore, p.287.
- Ganga G and Sulochana Chetty J. 1991. An Introduction to Sericulture. OXford & IBH, New Delhi, p.176.
- Ganga G 2003. Comprehensive Sericulture. Volume 2. Silkworm Rearing and Silk Reeling. Oxford & IBH, New Delhi, p.429.
- Govindaiah, Gupta VP, Sharma DD, Rajadurai S and Nishitha Naik V. 2005. Textbook on Mulberry Crop Protection, p 247.
- Jolly MS. 1987. Appropriate Sericulture Techniques. Central Sericultural Research and Training Institute, CSB, Mysore, p.215.
- Kamal Jaiswal, Sunil P Trivedi, Pandey, BN and Khatri RK. 2009. Moriculture, pp. 130-147.
- Kichisaburo Minamizawa. 1984. Moriculture: Science of Mulberry Cultivation, pp. 372-402
- Rangaswamy G, Narasimhanna MN, Kasiviswanathan K, Sastry CR and Jolly M. 1976. Manual on Sericulture-I.Mulberry Cultivation, FAO, Rome, P.150.

- Savithri G, Sujathamma P and Neeraja P. 2016. Sericulture industry: an overview, pp. 28-35. Ullal, S.R. and Narasimhanna, M.N. 1981. Handbook of Practical Sericulture, CSB, P.209.

Journals

- Bulletin of Indian Academy of Sericulture, CSTRI, Berhampore
- Indian silk, CSB, Bangalore
- Journal of Sericultural Science of Japan, Japan
- Seridoc, CSRTI (CSB), Mysore
- Sericologia, ISC, Bangalore
- Korean Journal of Sericulture, Korea
- Indian Journal of Sericulture, CSRTI (CSB), Mysore
- And other Periodicals, Journals, Reports, Brochures, etc.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/x

I. Course Title : Genetics and Breeding of Mulberry

II. Course code : SER 502

III. Credit Hours : 1+1

IV. Why this course ?

Mulberry is perennial and highly heterozygous crop. In order to develop high yielding mulberry varieties for different situations, genetic principles and different breeding methods are prerequisite. In order to improve mulberry genetically, knowledge on different aspects of origin and diversity, floral structure, biology and pollination, genetic basis and concept of breeding, use of germplasm and conventional methods and non-conventional methods of breeding is essential. Hence this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of mulberry origin and diversity, floral structure, biology and pollination, genetic basis and general concept of breeding. Establishment of germplasm and genetic improvement of mulberry by conventional and non-conventional methods of breeding are dealt.

The course is organised as follows :

No.	Blocks	Units	
1.	Taxonomy and botanical description	I	Origin and diversity studies of mulberry and classification of mulberry
		II	Study of floral structure, biology and pollination
		III	Genetic basis and general concept of mulberry breeding
2.	Mulberry germplasm and breeding methods	I	Mulberry germplasm
		II	Conventional methods of breeding
		III	Non-conventional methods of breeding

VI. Theory

BLOCK 1: Taxonomy and botanical description and classification of mulberry

Unit 1: Origin and diversity studies of mulberry

Centre of origin and diversity studies of mulberry, Mulberry species and their distribution in India and other countries. Taxonomy of the genus Morus. Botanical description of the Morus spp.

Unit 2: Study of floral structure, biology and pollination

Reproduction and genetic constitutions in mulberry –asexual reproduction- characteristics of mulberry florets- sexual behaviour- anthesis-reproductive variability. Pollination in mulberry. Cytology of mulberry, cell division- mitosis and meiosis and their significance. Karyomorphological studies. Microsporogenesis and Megasporogenesis in mulberry. Embryological studies of mulberry.

Unit 3: Genetic basis and general concept of mulberry breeding

Expression of gene: Segregation of genes, linkage, homozygosis, quantitative inheritance, features of polygenic inheritance, population structure, Selection of Parents for Hybridization. Procedure of Hybridization:Pruning and Synchronization of Flowering, Bagging, Tagging, Pollination. Harvesting and storing of F1 seeds, Raising F1 generation. Seedling Selection criteria. Difficulties in hybridization, Consequences of hybridization. Combining ability: general combining ability and specific combining ability, Heritability, genetic advance and genetic divergence.

BLOCK 2: Mulberry germplasm andbreeding methods

Unit 1: Mulberry germplasm

Establishment of mulberry,objectives and need, exploration, collection and introduction of mulberry germplasm, acclimatization and utilization. Introductions, world collection of mulberry germplasm, plant quarantine, conservation and maintenance of mulberry germplasm, characterization and evaluation of mulberry germplasm, role of mulberry germplasm study in mulberry improvement.

Unit 2: Conventional methods of breeding

Objectives and pre-requisites of mulberry breeding. Genetics of important traits. Early works of mulberry breeding, problems associated with mulberry breeding, conditions favouring mulberry breeding. Reproductive systems and plant breeding methods, Pollination in mulberry and crossing techniques. Mulberry varieties developed through direct selection, selection without controlled pollination, controlled pollination methods, handling of segregating progenies, Conventional methods of breeding- introduction, clonal selection, backcross method. Intervarietal and distant hybridization. Heterosis breeding. Population improvement. Polycross hybrids – Principles involved, advantages and disadvantages, steps in development of polycross hybrids. Multilocational trial and mulberry authorization programme, testing of feed quality. Advanced generation breeding. Improved varietal evaluation distribution and maintenance. Challenges for future.

Unit 3: Non-conventional methods of breeding

Polyploidy breeding in mulberry: Introduction, origin of polyploids, general features of polyploidy, induction of polyploidy and optimal level, special features of triploids, process of triploid mulberry development, varieties developed by polyploidy breeding in mulberry.

Mutation breeding in mulberry: Induction of mutation, bud mutation and chimeras, mutation breeding achievements in mulberry, usefulness of induced mutation, cutting back treatment, limitations and achievements of mutation breeding in mulberry.Breeding for leaf quality, resistance against diseases and pests, tolerance for drought, alkalinity and salinity. Evaluation of mulberry genotypes for different growth and yield parameters. Centres involved in mulberry improvement. Statistical approaches for yield test: Field plot techniques in mulberry breeding experiments. Different experimental designs- RCBD, ARCBD and LSD. Recent approaches in mulberry improvement: In-vitro techniques- achievements and prospects.

VI. Practicals

- Floral structure of mulberry;
- Floral biology of mulberry;
- Practising of staggered pruning in mulberry for inducing flowering;
- Sporogenesis: Micro and Megasporogenesis in mulberry;
- Preparation of mitosis slides in mulberry;
- Preparation of meiosis slides in mulberry;
- Study of pollen morphology, pollen fertility and viability;
- Study of stigma receptivity;
- Pollination and crossing techniques in mulberry;
- Characterization of available mulberry germplasm;
- Collection of mulberry fruits, extraction of seeds and raising of seedlings;
- Practising of selection in segregating population/ progenies;
- Study of varietal characteristics of released mulberry varieties;
- Layout of field experiments in mulberry for yield evaluation;
- Techniques of induction of mutants and polyploidy in mulberry;
- Testing for resistance to biotic and abiotic stresses in mulberry;
- Breeding for quality improvement in mulberry;
- Visit to Germplasm research station, CSGRC, Hosur.

VII. Teaching Methods/ Activities

– Lectures
– Assignments (Reading/ Writing)
– Text book/ Publication reviews
– Student presentations
– Group work
– Students interview of key policy makers
– Case analysis and case studies, guest lectures
– Review of policy documents

IX. Learning Outcome

After successful completion of this course the students are expected to be able to get equipped with the different breeding methods for improvement of mulberry.

X. Suggested Reading

- Amitabh Sarkar. Mulberry breeding. Kalyani publication, New Delhi.
- Chakraborti SP, Roy Chowdhuri S and Bindroo BB. 2013. A text book on mulberry breeding and genetics. Kalyani publications, New Delhi.
- Dandin SB. 1986. Mulberry breeding for tropics. In “Lectures on Sericulture” Edt. (G. Boraiah), Suriamya Publishers, Bangalore, pp. 25-28.
- Das BC and Krishnaswami S. 1969. Estimation of components of variation of leaf yield and its traits in mulberry. Indian J. Seric., 9(1): 26-30.

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- Das BC and Katagiri K. 1968. Germination and storage of pollen on its viability. Indian J. Seri., 10(1): 37-41.
- FAO. Manual of sericulture Vol-1.
- Giridhar K. 1996. Studies on some improved varieties of mulberry and their influence on the silkworm, Bombyx mori L. Ph. D. Thesis, Mysore University, Mysore, India.
- Jalaja KS and Ram Rao DM. 2008. Characterization of seven mulberry genotypes for their leaf quality and bioassay with silkworm, Bombyx mori L. Sericologia, 48(1):85-93.
- Machii H, Koyama A, Yamanuchi H and Katagiri K. 1997. Manual for the characterization and evaluation of genetic resources. Misc. Natl. Inst. Seri. Entomol. Sci., 22: 105-124.
- Machii M. 1990. Leaf disc transformation of mulberry plant (Morus alba L.) by Agrobacterium Ti plasmid. J. Seric. Sci. Japan, 59: 105-110.
- Masilamani S, Reddy AR, Sarkar A, Sreenivas BT and Kamble CK. 2000. Heritability and genetic advance of quantitative traits in mulberry (Morus spp.). Indian J. Seric., 13(1): 16- 20.
- Mogili T, Sarkar A Reddy and Munirathnam 2002. Effect of saliniy stress on some improved varieties of mulberry, Morus spp. Sericologia, 42(2): 149-163.
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- Rangaswami G, Narasimhanna MN, Kasiviswanathan K, Sastry CR and Jolly MS. 1978. Manual of Sericulture. Vol. 1 Mulberry Cultivation, FAO, Rome, p.150.
- Sarkar A and Fujita H. 1993b. Japanese system of mulberry breeding: First selection. Indian Silk, September, 9-14.
- Sarkar A, Jalaja Kumar S and Datta RK. 2000. Gradual improvement of mulberry varieties under irrigated condition in South India and the optimal programme for varietal selection in the tropics. Sericologia, 12: 142-148.
- Sastry CR. 1984. Mulberry varieties, exploitation and pathology. Sericologia,24(3): 333-359. Singh BD. Plant breeding Principles and methods. Kalyani publication, New Delhi.
- Susheelamma BN, Jolly MS, Sharma Giridhar K, Dwivedi NK and Suryanarayana N. 1988. Correlation and path analysis in mulberry under stress and non-stress conditions. Sericologia, 28(2): 239-243.

Journals

- Bulletin of Indian Academy of Sericulture, CSTRI, Berhampore
- Indian silk, CSB, Bangalore
- Journal of Sericultural Science of Japan, Japan
- Seridoc, CSRTI (CSB), Mysore
- Sericologia, ISC, Bangalore
- Korean Journal of Sericulture, Korea
- Indian Journal of Sericulture, CSRTI (CSB), Mysore
- And other Periodicals, Journals, Reports, Brochures, etc.Websites
- www.csb.gov.in/
- https://www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Systematics and Morphology of Sericigenous insects

II. Course Code : SER 506

III. Credit Hours : 2(1+1)

IV. Why this course ?

This course gives an impetus to study the morphological differences among sericigenous insects and to define new eco-races adopting morpho taxonomy, chemo taxonomy; to establish and explore new sericigenous fauna in different agro climatic zones.

V. Aim of the course

To inculcate basic systematics study among the students and to explore new fauna among sericigenous group of insects. Defining new genara, species and tribes in sericigenous insects in various habitats of different Agro-climatic zones of Karnataka/ India

The course is organized as follows :

No.	Blocks	Units	
1.	Morphological studies	I	Introduction to Morphology
		II	Morphology of integument
		III	Morphology of body segments and appendages
2.	Systematics of sericigenous insects	I	Introduction, scope and methods
		II	Type concept
		III	Preparation of keys
		IV	Zoological nomenclature

VI. Theory

BLOCK 1: Morphological studies

Unit 1: Introduction to morphology

Introduction, general morphology with special reference to the morphology of sericigenous insects.

Unit 2:Morphology of integument

Structure, segmentation and out growths, body regions, appendages and other structures, their modifications in general.

Unit 3: Morphology of body segments and appendages

Morphology of head, thorax, abdomen and their appendages, antennae, mouthparts, setae, legs, cerci, styli and others. Morphology of reproductive organs – modifications.

BLOCK 2: Systematics of sericigenous insects

Unit 1: Introduction, scope and methods

Introduction to systematics: Concept, scope and applications, methods involved in systematics.

Unit 2:

Holotype, syntype, erection of type and preservation of type.

Unit 3: Preparation of keys

Key formation for sericigenous insects to identify orders, families, genera, species and tribes/ eco-races.

Unit 4: Zoological nomenclature

Binomial nomenclature; concept, scope and application.

VII. Practicals

- Study of head of sericigenous insects;
- Study of thorax and abdomen of sericigenous insects;
- Study of integument, their processes, out growths and setal maps;
- Preparation of temporary/ permanent slides to study the processes;
- Drawing of sketches using grid and camera lucida;
- Collection and preservation of specimens – whole specimen, dry/ wet preservation, labelling of the specimens;
- Study of type concept – Hollotype, Syntype and allotype;
- Preparation of keys to orders, families, genera, species and tribes;
- Study of different sericigenous insects by making diagrams;
- Study of Chaetotaxy in sericigenous insects;
- Study of immature stages of silkworm Bombyx mori L.;
- Study of immature stages of Tropical Tasar silkworm;
- Study of immature stages of Eri silkworm;
- Study of Polymorphism in silkworm Bombyx mori L., Tropical Tasar and Eri silkworm;
- Field visits for collection of Non-mulberry silkworms;
- Collection and preservation of sericigenous insects (Dry preservation);
- Collection and preservation of immature stages of sericigenous insects (Wet preservation);
- Visit to Taxonomic section of department of entomology to understand preservation of specimens and their management.

VIII. Teaching Methods/ Activities

- Lectures
- Collections, preservation of specimens and submission of different species of sericigenous insects
- Drawing of specimens – habitat sketches using camera lucida and grids
- Photography of specimens using scientifically advanced camera
- Micro photography/ photo microscopy of specimens
- Preparation of permanent slides
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected

- To identify the sericigenous fauna
- To understand the basic principles of morphology
- To understand the basic principles of systematics
- Understanding the Type concept, erection of types
- To establish confidence in systematics of sericigenous insects

X. Resources

- Dilip De Sarkar. 1998. The Silkworm – Biology, Genetics and Breeding. Vikas Publishing House Pvt. Ltd., New Delhi.
- Imms AD. 1961. General Text Book of Entomology. 9th Edn., Rev. by O.W. Richards & R.G. Davies, Bombay.
- Saxena AB. 1996. Development of Behaviour in Insects. Anmol Publications Pvt. Ltd., New Delhi.
- Saxena AB. 1996. Principles of Insect Morphology. Anmol Publications Pvt. Ltd., New Delhi.
- Saxena AB. 1996. Ecology of Insects. Anmol Publications Pvt. Ltd., New Delhi.

Journals

- Bulletins of Sericultural Experimental Station - Suginami, Tokyo, Japan.
- Journal of Sericultural Science of Japan - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- Sericologia - Jacques Rousseau, 69350, La Mulatiere, France.
- Indian Journal of Sericulture - CSR & TI, Mysore.
- Journal of Sericulture and Technology - Published by NASSI, Bangalore.
- Indian Silk - Central Silk Board, Bangalore.
- Bulletin of Indian Academy of Sericulture - Bhubaneshwar, Orissa.
- Reshme Krishi (Kannada) - Department of Sericulture, Government of Karnataka, Bangalore.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Silkworm Egg Production Technology

II. Course Code : SER 509

III. Credit Hours : 2(1+1)

IV. Why this course ?

The silk cocoon yield and productivity directly depend on quality of silkworm eggs produced and distributed to the farmers. The silkworm egg production should be organized and handled scientifically for good quality disease free egg production at both seed and at commercial egg production. The present course is designed to make the student understand the organization of egg production and Acts associated with silkworm seed production, establishment of grainage, grainage equipments, activities, mother moth examination for disease free layings, egg incubation and preservation schedules, production of hybrid seeds and economics of egg production.

V. Aim of the course

The course is formulated with the aim of equipping the PG students with best scientific and practical knowledge on all the activities of egg production starting from organizational setup of seed production, grainage equipment, grainage activities, mother moth examination for producing student community of scientific and high technology expertise.

The course is organised as follows:

No.	Blocks	Units	
1.	Organization of egg production	I	Three tier multiplication of silkworm seeds
		II	Seed Act
2.	Grainage	I	Establishment of grainage
		II	Grainage activities
3.	Artificial Hatching of eggs	I	Production of hybrid eggs
		II	Artificial methods of hatching

VI. Theory

BLOCK 1: Organization of egg production

Unit 1: Three tier multiplication of silkworm seeds

Organization of egg production. Breeder stock, foundation stock and commercial egg production (egg cards and loose egg preparation).

Unit 2: Seed Act, Seed legislative act, 1959. Seed Act 2010.

BLOCK 2: Grainage

Unit 1: Establishment of grainage

Location of grainage, plan of grainage, grainage equipments and capacity of grainage.

Unit 2: Grainage activities

Seed areas, seed cocoon market, procurement and transportation of seed cocoons, selection, storage, handling and processing of seed cocoons. Sex separation in pupal stage, moth emergence, synchronization of moth emergence, pairing, depairing, moth examination, laying preparation on egg cards/ loose egg production, rejection of defective eggs, disinfection and washing and incubation of eggs.

BLOCK 3: Artificial Hatching of eggs

Unit 1: Production of hybrid eggs

Production of hybrid seeds (Multivoltine x Bivoltine), (Bivoltine x Bivoltine), (Bivoltine x Bivoltine) x (Bivoltine x Bivoltine) (Double Cross Hybrid). Grainage pests. Economics of egg production and special determinants.

Unit 2: Artificial methods of hatching

Artificial methods of hatching of bivoltine eggs, cold and hot acid treatments, physical and chemical methods, hibernation schedules.

VII. Practicals

- Silkworm breeds and their classification;
- Study of ground plan of model grainage building;
- Study of grainage equipments;
- Preliminary examination of seed cocoons for production of dfls, study of handling and processing of seed cocoons;
- Study of sex separation at pupal and adult stages;
- Study of Silkworm egg incubation;
- Study of silkworm egg hibernation schedules;
- Study of grainage pests and their management;
- Preservation of male moths for reuse;
- Preservation of male and female pupae for synchronization;
- Effect of mating duration on egg production and fertility status of eggs;
- Disinfection of grainage equipments;
- Designation of multivoltine and bivoltine seed areas in Karnataka;
- Estimation of cocoon requirement for production of unit number of DFLs;
- Production of non-hibernating eggs of silkworm;
- Production of hibernating eggs of silkworm (on egg cards and loose egg preparation);
- Artificial hatching of silkworm eggs through acid treatment;
- Economics of silkworm egg production.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

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

- Understand the organization of silkworm seed production structure, Grainage, silkworm egg pro uction, seed act, artificial methods of hatching, egg incubation and hibernation schedules
- Utilize this knowledge in producing healthy and quality seed production, serve the farming community with scientific grainage techniques for quality egg production.

X. Suggested Reading

- Anonymous. 1997. Silkworm Egg Production. OXford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.
- Dandin SB and Gupta VP. 2002. Advances in Indian Sericulture Research. CSR&TI, Mysore.

- Datta RK. 1996. Global Silk Scenario – 2001. Proceedings of the International Conference on Sericulture – 1994, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.
- Narasimhanna MN. 1998. Manual on Silkworm Egg Production. CSB, Bangalore.

Journals

- Bulletin of Sericultural Experimental Station - Suginami, Tokyo, Japan.
- Journal of Sericultural Science of Japan - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- Sericologia - Jacques Rousseau, 69350, La Mulatiere, France.
- Indian Journal of Sericulture - CSR & TI, Mysore.
- Journal of Sericulture and Technology - NASSI, Bangalore.
- Indian Silk - Published by Central Silk Board, Bangalore.
- Bulletin of Indian Academy of Sericulture - Bhubaneshwar, Orissa.
- Reshme Krishi (Kannada) - Department of Sericulture, Government of Karnataka, Bangalore.
- Current Science – Indian Institute of Science, Bangalore.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Silkworm Rearing Technology

II. Course Code : SER 510

III. Credit Hours : 2(1+1)

IV. Why this course ?

Silkworm rearing is the main contributing factor and plays a major role in quality cocoon production. It is important to know the different silkworm rearing methods for rearing young and late-age silkworms. The knowledge on scientific methods starting from egg incubation, black boxing, brushing, young age rearing, late age rearing, mounting of ripe silkworms, maintenance of environmental conditions during silkworm rearing, care during mounting, etc., is very important for sericulture experts to lead the sericulture community with a scientific and technical expertise.

V. Aim of the course

The course is designed with the aim of equipping the PG students with the best scientific knowledge and technical expertise in the field of silkworm rearing technology, different methods/ techniques involved in silkworm rearing, maintenance of environmental condition during rearing, etc., for quality silkworm production inturn contributing to the economy of individual farmer.

The course is organised as follows:

No.	Blocks	Units	
1.	Planning for silkworm rearing	I	Planning for chawki rearing and late age silkworm rearing
		II	Disinfection and disinfectants

		III	Mulberry leaf preservation
		IV	Incubation of silkworm eggs
2.	Silkworm rearing	I	Early instar silkworm rearing
		II	Late age silkworm rearing
3.	Mounting, harvesting and marketing of silk cocoons	I	Mounting of ripe worms and cocoon marketing
		III	Comparison of different rearing methods

VI. Theory

BLOCK 1: Planning for silkworm rearing

Unit 1: Planning for chawki rearing and late age silkworm rearing

Planning for rearing, criteria to be considered for rearing, plan of rearing house for chawki and late age silkworm rearing, rearing equipment, measurement and regulation of environmental factors.

Unit 2: Disinfection and disinfectants

Disinfection of rearing room and equipment.

Unit 3: Mulberry leaf preservation

Planning for silkworm rearing; harvesting, transportation and preservation of mulberry leaves.

Unit 4: Incubation of silkworm eggs

Different methods of incubation of silk moth eggs, hatching and brushing.

BLOCK 2 : Silkworm rearing

Unit 1: Early instar silkworm rearing

black-boxing, Early instar silkworm (Chawki) rearing, different methods, environmental conditions, quality of leaf, feeding, bed cleaning, spacing. Chawki rearing centres.

Unit 2: Late age silkworm rearing

Different methods of late age silkworm rearing, environmental conditions, feeding and bed spacing. Management of silkworm during moulting.

BLOCK 3: Mounting,harvesting and marketing of silk cocoon

Unit 1: Mounting of ripe worms and cocoon marketing

Mounting of ripe worms, different kinds of mountages. Rearing house and equipment for shoot method of rearing.

Unit 2: Comparison of different rearing methods

Comparing shoot feeding and shelf method of rearing.

VII. Practicals

- Ground plan for model rearing house for shelf method of rearing;
- Chemical and physical agents used in silkworm rearing and disinfection;

- Rearing equipments for shelf method of rearing;
- Incubation of silk moth eggs and black- boxing;
- Hatching and brushing;
- Early instar silkworm rearing;
- Late age silkworm rearing;
- Regulation of environmental conditions for silkworm rearing;
- Harvesting and preservation of mulberry leaf;
- Management of silkworms during moulting;
- Mounting of ripe silkworms;
- Cocoon harvesting, grading, transportation and marketing;
- Rearing house and equipment for shoot method of rearing;
- Shoot feeding for late age silkworm rearing;
- Harvesting and preservation of mulberry shoots;
- Spacing and bed cleaning in shoot feeding method of silkworm rearing;
- Economics of silkworm rearing;
- Rearing from brushing to mounting for seed and silk production.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

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

Understand thoroughly the scientific silkworm rearing techniques, scientific management of silk-worms during special conditions like during mounting, mulberry care, spinning stage, etc., inturn contributing to build a technically competent Sericultural expertise.

X. Suggested Reading

- Anonymous. 1998. Illustrated Textbook on Sericulture. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.
- Boraiah G. 1994. Lectures on Sericulture. SBS Publishers, Bangalore.
- Dandin SB and Gupta VP. 2002. Advances in Indian Sericulture Research. CSR&TI, Mysore.
- Dandin SB, Jayant Jayaswal and Giridhar K. (Eds.) 2003. Handbook of Sericulture Technologies. CSB, Bangalore.
- Datta RK. 1996. Global Silk Scenario – 2001. Proceedings of the International Conference on Sericulture – 1994. OXford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

- Govindan R, Chinnaswamy KP, Krishnaprasad NK and Reddy DNR. 2000. Advances in Tropical Sericulture. Vol. 4– Proceedings of NSTS – 1999, UAS, Bangalore.
- Govindan R, Devaiah MV and Rangaswamy HR. 1978. Reshme Vyavasaya (Kannada). UAS, Bangalore.
- Hiroo and Sibuya-ku. 1975. Textbook of Tropical Sericulture. Japan Overseas Corporation Volunteers, Tokyo, Japan.
- Krishnaswami S, Narasimhanna MN, Suryanarayan SK and Kumararaj S. 1973. Sericulture Manual-2 - Silkworm Rearing. Agriculture Service Bulletin, FAO, Rome.
- Rajan RK and Himantharaj HT. 2005. Silkworm Rearing Technology. Central Silk Board, Bangalore.
- Ramakrishna Naika, Govindan R and Sannappa B. 2002. Organic Sericulture. Seri Scientific Publishers, Bangalore.
- Tanaka Y. 1964. Sericology. Central Silk Board, Bangalore.
- Tazima Y. 1972. Handbook of Silkworm Rearing. Fuji Pub.Co. Ltd., Tokyo, Japan.
- Ullal SR and Narasimhanna MN. 1981, Handbook of Practical Sericulture. CSB, Bangalore. Yasuji Hamamura. 2001. Silkworm Rearing on Artificial Diet. OXford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.
- Yonemura M and Rama Rao N. 1925. Handook of Sericulture. Mysore Government Branch Press.

Journals

- Bulletin of Sericultural Experimental Station - Suginami, Tokyo, Japan.
- Journal of Sericultural Science of Japan - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- Sericologia - Jacques Rousseau, 69350, La Mulatiere, France.
- Indian Journal of Sericulture - CSR & TI, Mysore.
- Journal of Sericulture Technology – NASSI, Bangalore.
- Indian Silk - Central Silk Board, Bangalore.
- Bulletin of Indian Academy of Sericulture - Bhubaneshwar, Orissa.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Genetics and Breeding of Silkworms

II. Course Code : SER 511

III. Credit Hours : 2(1+1)

IV. Why this course ?

Silkworm crop improvement needs sustainable efforts in order to achieve higher silk productivity of superior quality. Understanding of genetic basis of expression of characters and application of this understanding for breeding silkworms that meet the present day scenario is essential. Hence, this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of silkworm genetics and principles of silkworm breeding. The subject is addressed to understand reproductive biology, hereditary traits and principles of silkworm breeding

The course is organized as follows:

No.	Blocks	Units	
1	Genetics of silkworm	I	Cytology
		II	Reproductive biology
		III	Inheritance of characters
2	Breeding of silkworm	I	Silkworm breeding resources
		II	Methods of silkworm breeding

VI. Theory

BLOCK 1: Genetics of silkworm

Unit 1: Cytology

Ancestor and cytological basis of origin of silkworms. Cytological aspects of silkgland and achievements in deciphering molecular biology of silk gene. Hormonal control mechanisms.

Unit 2: Reproductive biology

Phenomena of spermatogenesis and oogenesis with relevance to crossing over, cell division types in silkworms, synaptonemal complex, fertilization, chromosomes in silkworms. Sex determination, parthenogenesis, polypoidy, mosaics.

Unit 3: Inheritance of characters

Hereditary traits of importance in egg, larva, pupa-cocoon and adult. E- Group as a tool in genetics and significance. Linkage groups in silkworms. Sex linked inheritance, Quantitative and Qualitative Characters in silkworm breeding. Genetics of cocoon colours. Bombyx mori L. genome and latest genome sequence, Translocation of characters in metamorphic stages.

BLOCK 2: Breeding of silkworm

Unit 1: Silkworm breeding resources

Multivoltine and bivoltine races and hybrids. Silkworm germplasm and resource potential.

Unit 2: Methods of silkworm breeding

Methods of silkworm breeding and their importance with relevance to Indian scenario. Breeding for thermotolerance, disease resistance, special characters required for the nation and also for silk export. Sex linked and sexlimited races- their importance and need of the hour, Authorization and release of silkworm races.

VII. Practicals

- Study of mitosis and meiosis in silkworm;
- Study of oogenesis in silkworm;
- Study of spermatogenesis and fertilization in silkworms;

- Study of important hereditary traits in egg and larva of silkworm Bombyx mori L.;
- Study of important hereditary traits of pupa and cocoons of silkworm Bombyx mori L.;
- Study of important hereditary traits of adult Bombyx mori L.;
- Study of Marker genes and linkage groups in silkworm;
- Study of heterosis - working out heterosis, heterobeltiosis and standard heterosis for economic characters;
- Study of silkworm germplasam;
- Study of biometrical methods in silkworm breeding;
- Study of modern methods of silkworm breeding;
- Study of induction of parthenogenesis in silkworm breeds;
- Study of induction of polyploidy in silkworm breeds;
- Study of conventional methods of silkworm breeding;
- Study of breeding of newly evolved silkworm breeds;
- Study of breeding of non-mulberry silkworms;
- Study of breeding plans;
- Visit to CSGRC,CSB, Hosur.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Visits to Germplasam centers
- Scientific journals and periodicals

IX. Learning outcome

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

- Understand the reproductive biology, inheritance of traits and breeding methods
- Utilise this knowledge to plan for silkworm breeding activities.

X. Suggested Reading

- Anonymous. 1993. Principles and Techniques of Silkworm Breeding. ESCAP, UN, New York. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. p.111.
- Gardner EJ, Simmons MJ and Snustad DP. 1991. Principles of Genetics, John Willey& Sons Inc., New York. p. 649.
- Hiratsuka E. 1999. Silkworm Breeding. OXford & IBH Publishing Co. Pvt. Ltd., New Delhi. p. 500.
- Jolly MS, Sen SK, Sonwalker TN and Prasad GK. 1979. Non-mulberry Silks. FAO - Agricultural Service Bulletin, Rome. p. 178.

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- Sarker DD. 1998. The Silkworm Biology, Genetics and Breeding. Vikas Publishing House Pvt. Ltd., New Delhi. p. 338.
- Sarin C. 1990. Genetics. Tata McGraw – Hill Publishing Co. Ltd., New Delhi. p. 528.
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- Singh RK and Chaudhary BD. 1996. Biometrical Methods in Quantitative Genetic Analysis. Kalyani Publishers, New Delhi. p. 318.
- Sreeramareddy G. 1998. Silkworm Breeding. OXford & IBH Publishing Co. Pvt. Ltd., New Delhi.
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- Journal of Sericultural Science of Japan - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
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- Journal of Sericulture and Technology - NASSI, Bangalore.
- Indian Silk - Published by Central Silk Board, Bangalore.
- Bulletin of Indian Academy of Sericulture - Bhubaneshwar, Orissa.
- Reshme Krishi (Kannada) - Department of Sericulture, Government of Karnataka, Bangalore.
- Current Science – Indian Institute of Science, Bangalore.

Websites

- www.csb.gov.in/
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- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Diseases and Pests of Silkworm

II. Course Code : SER 512

III. Credit Hours : 2(1+1)

IV. Why this course ?

Silkworms are affected by a number of diseases caused by Microsporidia, fungi, viruses, bacteria and mixed infections and also attacked by insect pests. The exposure to these pathogens and pests results in mortality of silkworms and economic loss to the silkworm rearers. A better understanding of causative agents, symptoms, sources of infection, predisposing factors, transmission and management of silkworm diseases and pests is very important to improve cocoon productivity and maximize economic benefit to silkworm rearers by better avoidance/management of silkworm diseases and pests.

V. Aim of the course

The course is designed to provide both theory and practical knowledge regarding the subjects of Classification of disease-causing organisms of mulberry and non- mulberry silkworms including viral, fungal, bacterial, protozoan and mixed infections. Knowledge on their occurrence, causative agent, etiology, symptoms and infection, sources of infection, predisposing factors, transmission and management, symptoms, seasonal incidence of diseases associated with mulberry and non- mulberry silkworms is important. Diagnosis of different pathogens based on symptoms (external and internal), regulation of environmental factors contributing to diseases, prevention and control of diseases also attain importance. Know how on pests of mulberry and non-mulberry silkworms, uzi fly occurrence, nature and extent of damage, life-cycle and management, other pests and predators effecting silkworm crop and their management and pesticide toxicity/ residual toxicity, use of eco-friendly pesticides and biological control will also be dealt.

The course is organized as follows:

No.	Blocks	Units	
1.	Silkworm diseases and their	I	Importance and Classification management
		II	Silkworm pathogens, disease development and diagnosis
		III	Management of silkworm diseases
2	Silkworm pests and their	I	Ujifly, Exorista bombycis Louis—a major pest of silkworms.
		II	Other pests and predators affecting silkworm crop and their management.
		III	Pesticide toxicity

VI. Theory

BLOCK 1: Silkworm diseases and their management

Unit 1: Importance and classification

Taxonomic position of silkworm disease causing organisms including viruses, bacteria, fungi, protozoans, classification of various pests causing economic loss to silkworms, and their importance.

Unit 2: Silkworm pathogens, disease development and diagnosis

Occurrence, causative agent, symptoms and infection, source of infection, predisposing factors, seasonal incidence, transmission and management of the pathogens individually including viral, fungal, bacterial, protozoan and mixed infections. Diagnosis of different pathogens based on symptoms (external and internal), patho-physiology and histopathology.

Unit 3: Management of silkworm diseases

Comparative etiology of silkworm pathogens. Management, prevention and control of diseases of silkworms, regulation of predisposing and environmental factors contributing to diseases, rearing disease resistant breeds of silkworm. Management of alternative hosts of silkworm disease causing pathogens (lepidopteran crop pests and pests of mulberry). Intergrated disease management.

BLOCK 2: Silkworm pests and their management

Unit 1: Ujifly, Exorista bombycis Louis - a major pest of silkworms

History and taxonomy, Bio-ecology, Life cycle-egg, maggot, pupa, adult, oviposition, damage and extent of damage caused, prevention and control, biological control and IPM.

Unit 2: Other pests and predators affecting silkworm crop and their management

Pests and predators causing loss to silkworms and cocoons including Ants, type of damage, management. Straw itch mite, life cycle, kind of damage, management.

Dermestid beetles, classification, life cycle, nature of damage, management. Rats, squirrels, lizards, earwigs, etc.,

Unit 3: Pesticide toxicity

Poisoning by agricultural chemicals to silkworms, acute and chronic symptoms of poisoning by different agricultural chemicals. Residual toxicity of chemicals on mulberry and damage caused, prevention and control.

VII. Practicals

- Sterilization techniques for isolation of silkworm pathogens;
- Isolation and purification of BmNPV;
- Isolation and purification of BmCPV;
- Isolation and purification of BmIFV and BmDNV;
- Isolation and purification of white muscardine fungus Beauveria bassiana from silkworm Bombyx mori;
- Isolation and purification of brown muscardine fungus Aspergillus tamarii from silkworm Bombyx mori;
- Isolation and purification of bacteria from the gut and haemolymph of silkworm Bombyx mori;
- Study of life cycle, symptoms and diagnosis of BmNPV;
- Study of life cycle, symptoms and diagnosis of BmCPV;
- Study of life cycle, symptoms and diagnosis of BmIFV and BmDNV;
- Study of life cycle, symptoms and diagnosis of silkworm microsporidiosis;
- Study of life cycle, symptoms and diagnosis of white and green muscardines;
- Study of bacteria invading the digestive system and haemolymph;
- Study of bacterial toxicosis in mulberry silkworm;
- Intergrated management for prevention of silkworm diseases;
- Study of life-cycle of silkworm ujifly and its management;
- Study of life cycle and management of dermestid beetles;
- Visit to sericulture farmers fields.

VIII. Teaching Methods/ Activities

– Lectures
– Assignments (Reading/ Writing)
– Text Books
– Student presentations
– Experimentation
– Group discussion
– Group work
– Laboratory exercises
– Scientific journals and periodicals

IX. Learning outcome

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

– Appreciate the scientific foundation of silkworm protection and relate the key learning for further scientific research in the area of silkworm protection.
– Utilise methods and tools for prevention and management of diseases and pests of silkworms.
– Utilise material in scientific publications relevant for silkworm protection for enhancing cocoon crop productivity through effective management of silkworm diseases and pests.

X. Suggested Reading

- Dandin SB and Giridhar K. 2014. Handbook of Sericulture Technologies; Central Silk Board, Ed., Dr., pp 247.
- Govindan R, Narayanaswamy TK and Devaiah MC. 1998. Principles of Silkworm Pathology, p.420.
- Nataraju B, Sathyaprasad K, Manjunath D and Aswani Kumar C. 2005. Silkworm Crop Protection. Central Silk Board, Bangalore, pp. 1-285.
- Pringle Jameson A. 1984. Report On The Diseases of Silkworms In India, IBS, New Delhi, pp. 1-64.

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- Bulletins of Sericultural Experimental Station - Suginami, Tokyo, Japan.
- Journal of Sericultural Science of Japan - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- Sericologia - Jacques Rousseau, 69350, La Mulatiere, France.
- Indian Journal of Sericulture - CSR & TI, Mysore.
- Journal of Sericulture and Technology - NASSI, Bangalore.
- Indian Silk - Published by Central Silk Board, Bangalore.
- Bulletin of Indian Academy of Sericulture - Bhubaneshwar, Orissa.
- Reshme Krishi (Kannada) - Department of Sericulture, Government of Karnataka, Bangalore.

Websites

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- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Silk Technology-I

II. Credit Hours : 2(1+1)

III. Course code : SER 514

IV. Why this course ?

Sericulture is an agro based industry, which concentrates on production of quality leaf, cocoon and raw silk. The raw silk production by reelers from different machineries plays an important role in fabric production. Therefore, cocoon is considered as raw material for silk reeling industry which has to be processed by adopting recent techniques in all aspects of reeling that aim at quality raw silk production. The knowledge on recent techniques serves as an effective tool in reeling cocoons which throws light to produce competitive technical man power in processing of raw material. Hence is this course.

V. Aim of the course

The course is designed to make the students to get acquainted with activities in different reeling units operated both in private and government sectors. These activities will help in learning all techniques of silk reeling for quality raw silk production. In addition, they get knowledge on responsibilities of reeling units on management of labour and exploitation of reeling waste generated for by-product utilization.

Organisation of course:

No.	Blocks	Units	
1	Cocoon as raw material	I	Physical characteristics
		II	Commercial characteristics
2	Transaction of cocoons	I	Defective cocoons
		II	Cocoon marketing
3	Steps in silk reeling	I	Cocoon stifling
		II	Cocoon cooking and brushing
		III	Cocoon reeling
		IV	Re-reeling
		V	Reeling water
4	Silk testing and examination	I	Different methods of silk examination
		II	Silk testing and grading
5	Post reeling technology	I	Doubling, twisting and weaving
		II	Marketing of raw silk.

VI. Theory

BLOCK 1: Cocoon as raw material

Unit 1: Physical characteristics

Introduction; Importance and use of silk, cocoon quality. Physical characteristics- cocoon colour, shape, size, wrinkles, uniformity and compactness.

Unit 2: Commercial characteristics

Cocoon weight, shell weight, shell percentage, filament length, denier, non-breakable filament length, reelability and raw silk percentage.

BLOCK 2: Transaction of cocoons

Unit 1: Defective cocoons

Types of defective cocoons, reasons for defective cocoons, cocoon sorting, methods of sorting, estimation of defective cocoons per kg. Technological aspects. Selection of raw material for silk reeling – scientific method of testing and classification of cocoons.

Unit 2: Cocoon marketing

Marketing based on visual observation and based on quantitative parameters, open auction system (Quality based pricing) and E- transaction. Limitations of open auction system and estimation of renditta.

BLOCK 3: Steps in silk reeling

Unit 1: Cocoon stifling

Definition, different methods of stifling of cocoons - sun drying, steam stifling, hot air drying (shelf carrier type, Tunnel type, Band type- hot air circulating, air heating type and one step band type) and other methods. Effect of storage on stifling. Moisture percentage, Phenomenon of cocoon drying, drying percentage, equilibrium moisture percentage (Phenomenon of moisture evaporation). Effect of cocoon thickness and compactness on cocoon stifling, advanced system of cocoon stifling and machineries.

Unit 2: Cocoon cooking and brushing

Cocoon cooking- objectives of cocoon cooking, effect of pressure and temperature on infiltration of water into cocoon cavity, swelling of sericin layer, different methods of cooking (Open pan, two pan and three pan cooking system). Brushing of cocoons, different methods of brushing. Effect of temperature on solubility of sericin and fibroin layers, dipping period and brushing.

Unit 3: Cocoon reeling

Cocoon reeling- definition, different methods of reeling (Open/ Floating/ Sunken), Importance of croissure, length of the croissure and croissure angle and silk reeling, reeling machineries – Silk reeling on charaka, cottage basin, multiend, semi automatic and automatic reeling machines.

Unit 4: Re-reeling

Re-reeling, reel permeation, different methods of permeation, re-reeling methods, advantages and disadvantages of open re-reeling and closed type of re-reeling.

Unit 5: Reeling water

Reeling water: Different sources of water used in reeling, characteristics/ Properties of water (Impurities of water), Physical and chemical properties of water, Importance of reeling water, water qualities suggested by Kim and amelioration of water, different methods of amelioration (aeration, filtration, sedimentation and ion exchange method), amelioration of reeled water and reuse of water after treatment.

BLOCK 4: Silk testing and examination

Unit 1: Different methods of silk examination

Different silk examination methods and lacing, book and bale making.

Unit 2: Silk testing and grading

Silk testing and grading-grading of raw silk based on I.S.A., silk testing tools for physical (visual inspection) and mechanical properties of silk. Procedure adopted for conducting physical and mechanical properties of silk and equipments used for testing of raw silk.

BLOCK 5: Post reeling technology

Unit 1 : Doubling, twisting and weaving

Silk throwing, weaving, warping and wefting, silk doubling and twisting, by-products of reeling units, types of reeling waste (brushing waste, reeling waste, cooking waste, re-reeling waste, throwing waste and pelade layer) as raw material for spun silk industry.

Unit 2: Marketing of raw silk

Factors influencing the assessment of rawsilk quality. Role of silk exchange, auctioning of raw silk based on physical and mechanical properties and economics of silk reeling.

VII. Practicals

- Classification of cocoons of silkworm breeds;
- Study of Physical and Commercial characters of cocoons;
- Study of mode and time of cocoon transportation and marketing;
- Cocoon sorting, methods and estimation of defective cocoons;
- Cocoon stifling methods and estimation of drying and moisture percentage;
- Practising of cocoon cooking and brushing methods;
- Estimation of reeling and cooking waste percentage;
- Reeling appliances and practising reeling on Charaka and improved Charaka;
- Study of reeling appliances and practising reeling on Cottage basin and Domestic basin;
- Visit to government filature to acquaint with large scale reeling on Multiend reeling machine;
- Visit to Automatic reeling machine unit at Ramanagara;
- Silk examination, skein making and book making;
- Study of Reeling water and its quality;
- Amelioration of silk reeling water and its importance;
- Study of physical properties of mulberry raw silk;
- Study of microscopic examination of silk bave;
- Study of quality tests of raw silk and By-products in silk reeling;

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After undergoing this course the students are able to assess the quality of cocoon as raw material for reeling industry and acquaint with different techniques of reeling in quality silk production.

X. Suggested Reading

- Bhaskar RN and Govindan R. 2005. Techniques in Silk Reeling, Department of Sericulture, UAS,GKVK, p.50.
- Ganga G. 2003. Comprehensive Sericulture. Volume 2. Silkworm Rearing and Silk Reeling. Oxford & IBH, New Delhi, p.429.
- Kamal Jaiswal, Sunil P Trivedi, Pandey BN and Tripathi AK. Mulberry sericulture problems and prospects, A P H publishing corporation, New Delhi.

- Kim BH. 1978. Raw Silk Reeling, Korean edition Seoul Publishing Company, P 275.
- Krishnaswami S, Madhava Rao NR, Suryanarayan SK and Sundaramurthy TS. 1972. Manual on Sericulture-III.Silk Reeling, FAO, Rome, p.112.
- Mahadevappa D, Halliyal VG, Shankar AG and Bhandiwad R. Mulberry silk reeling technology, Oxford & IBH publishing Co. Pvt. Ltd.
- Manual on Bivoltine silk Reeling Technology. 2003. Published by JICA, PPP BST Project, p.122 Savithri, Sujathamma and Neeraja, Sericulture industry: An overview.
- Tripurari S. Sericulture and silk industry, Consortium on rural technology, Madhuvan, Delhi.

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- Bulletins of Sericultural Experimental Station - Suginami, Tokyo, Japan.
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- Sericologia - Jacques Rousseau, 69350, La Mulatiere, France.
- Indian Journal of Sericulture - CSR & TI, Mysore.
- Journal of Sericulture and Technology - NASSI, Bangalore.
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- Bulletin of Indian Academy of Sericulture - Bhubaneshwar, Orissa.
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Websites

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- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Non-mulberry Sericulture

II. Course Code : SER 515

III. Credit Hours : 2(1+1)

IV. Why this course ?

This course enlightens various types of silk producing insects, viz., Tasar, Eri and Muga and their production techniques. Thishighlights wild rearing in-situ in forest area and also semi domestication of wild non-mulberry silks. This also helps to explore possibilities of new sericigenous insects and other minor silk producers.

V. Aim of the course

This course is designed to provide basic and applied aspects of non-mulberry sericulture. This course will approach multi-disciplinary perspective, it aims to equip students to identify, evaluate and explore new species of sericigenous insects to address the tribals self employment programme.

The course is organized as follows :

No.	Blocks	Units	
1.	Underexploited non-mulberry silks	I	Scope, importance, distribution in the World

		II	Introduction to Anaphe, Coan and Fagara silks
2.	Commercially exploited non-mulberry silks	I	Scope, importance and their distribution in the World
		II	Rearing of Eri silkworms
		III	Rearing of Tasar (tropical/ temperate)
		IV	Rearing of Muga silkworms
		V	Economics of non-mulberry silkworm rearing

VI. Theory

BLOCK 1: Underexploited less known non-mulberry silks

Unit 1: Scope, importance and distribution in the World

Uses of less known sericigenous species for commercial exploitation, distribution pattern on different host plants and their statistics.

Unit 2: Introduction to Anaphe, Coan and Fagara silks

Systematics, morphology and cocoon characteristics of Anaphe, Fagara, Coan silks and possibilities of their exploitation.

BLOCK 2: Commercially exploited non-mulberry silks

Unit 1: Scope, importance and their distribution in the world

Scope, importance, distribution in the country and World of Eri, Tropical Tasar, Temperate Tasar and Muga silks and their primary and secondary host plants.

Unit 2: Rearing of Eri silkworm

Host plant distribution and their classification, agronomic practices and their protection, grainage techniques, rearing of eri using improved techniques and crop protection.

Unit 3: Rearing of Tasar (tropical/ temperate)

Host plant distribution and their classification, agronomic practices and their protection, grainage techniques, rearing of tropical/ temperate tasar using improved techniques and crop protection.

Unit 4: Rearing of Muga silkworms

Host plant distribution and their classification, agronomic practices and their protection, grainage techniques, rearing of muga silkworms using improved techniques and crop protection.

Unit 5: Economics of non-mulberry silkworm rearing

Economics of non-mulberry silkworm rearing, viz., eri, tasar and muga silkworm rearing and their cost benefit ratio.

VII. Practicals.

- Study of primary and secondary host plants of eri silkworm;
- Study of primary and secondary host plants of tasar silkworm;
- Study of primary and secondary host plants of muga silkworm;
- Cultivation of popular castor genotypes for eri silkworm rearing;
- Preparation of rearing house for eri silkworm rearing;

- Rearing of eri silkworm on different castor genotypes;
- Calculation of consumption indices in eri silkworm using leaves of different castor genotypes;
- Collection and dry preservation of different primary and secondary host plants of non-mulberry silkworms;
- Preparation of disease free layings of eri silkworm;
- Morphology of eggs and larvae of eri silkworm;
- Morphology of pupa and moth of eri silkworm;
- Morphology of eggs and larvae of tasar and muga silkworms;
- Morphology of pupa and moth of tasar and muga silkworms;
- Effect of different mating durations on fecundity and fertility of eri silk moths;
- Study of different natural enemies of eri silkworm;
- Study of different diseases of eri silkworm;
- Practising of tasar egg production;
- Economics of eri silkworm rearing;
- Visit to Eri Silkworm Seed Production Centre, CSGRC Hosur, CSB.

VIII. Teaching Methods/ Activities

- Lectures
- Collections of various non-mulberry silkworms
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

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

- acquire skills on rearing of vanya silks, their host plants and rearing technologies. In addition, it enables to explore less known silkworm species and exploit them.

X. Suggested Reading

- Jolly MS, Sen SK and Ahsan MM. 1974. Tasar culture. Ambika Publishers, Bombay.
- Jolly MS, Sen SK Sonwalkar TN and Prasad GK. 1979, Sericulture Manual - 4 – Non-Mulberry Silks. Agriculture Service Bulletin, FAO, Rome.
- Sannappa B, Jayaramaiah M., Govindan R and Chinnaswamy KP. 2002, Advances in Ericulture.
- Seri Scientific Publishers, Bangalore.
- Sarkar DC. 1980. Ericulture in India. Central Silk Board, Bangalore.

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- Bulletins of Sericultural Experimental Station - Suginami, Tokyo, Japan.
- Journal of Sericultural Science of Japan - Sericultural Experimental Station, Wade, Suginami-ku,

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- Sericologia – Jacques Rousseau, 69350, Ls Mulatiere , France.
- Indian Journal of Sericulture - CSR & TI, Mysore.
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- Bulletin of Indian Academy of Sericulture - Bhubaneshwar, Orissa.
- Reshme Krishi (Kannada) - Department of Sericulture, Government of Karnataka, Bangalore.

Websites

- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

M.Sc. (Community Science)

COMMUNITY SCIENCE

Course Title with Credit Load

M.Sc. (Community Science) in Food and Nutrition

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
FN 501	Macro and Micro Nutrients in Human Nutrition	3(3+0)
FN 502	Public Health and Nutrition	3(2+1)
FN 503	Techniques in Food Analysis	3(1+2)
FN 504	Diet Therapy	3(2+1)
FN 505	Nutrition and Physical Fitness	3(2+1)
FN 506	Developments in Nutrition and Immunity	2(2+0)
FN 507	Clinical Nutrition	3(2+1)
FN 508	Nutrition Counselling	2(0+2)
FN 509	Food Safety and Standards	3(2+1)
FN 510	Nutritional Challenges in Life Cycle	3(3+0)
FN 511	Food Science	3(2+1)
FN 512	Food Processing Technology	3(2+1)
FN 513	Human Physiology	3(3+0)
FN 514	Institutional Food Service Management	2(1+1)

Course Contents

M.Sc. (Community Science) in Food and Nutrition

I. Course Title : Macro and Micro Nutrients in Human Nutrition

II. Course Code : FN 501

III. Credit Hours : 3(3+0)

IV. Rationale

Proper nutrition is the crux of human health along with safe water, sanitation, immunization, etc. Adequate knowledge about this core course on macro and micronutrients in totality will enable the students to handle the nutrition situations of a population and how to imply the knowledge for sustainable handling to induce better health and productivity. Therefore, the necessity lies in this core course.

V. Aim of the course

- To provide in-depth understanding related to macro and micro nutrients
- To impart knowledge about specific requirements of these nutrients as per age, sex, physiological condition, functions, metabolism sources, deficiency parameters for meaningful handling of normal and problem stricken situations.

VI. Theory

Unit I: Carbohydrates

Body composition; Functions, sources, requirements, digestion and absorption of carbohydrates. Composition, classification and functions of dietary fibre; Role of dietary fibre, resistant starch and fructo-oligosaccharides in various physiological disorders; Glycemic response to carbohydrates.

Unit II: Proteins

Classification, functions, sources, digestion and absorption of proteins; Synthesis of non-essential amino acids in the body; Urea cycle; Protein quality; Relationship between energy and protein requirements; Regulation of food intake; Nutrient adaptation to low intake of energy and protein.

Unit III: Fats

Classification, functions, sources, digestion, absorption and deficiency disorders of lipids and essential atty acids; Role of omega-3 and omega 6 fatty acids in physiological disorders.

Unit IV: Vitamins, minerals and water

Functions, absorption, requirement, sources, deficiency and toXicity of fat-soluble vitamins - A, D, E and K and water-soluble vitamins- thiamine, riboflavin, niacin, pyridoXine, folate, B12, ascorbic acid, pantothenic acid, biotin and amygdalin; Functions, absorption, requirement, sources, deficiency and toXicity of macro minerals – calcium and phosphorus and micro minerals – iron, zinc, sodium, copper, cobalt, selenium and chromium; Water and electrolyte balance, functions and distribution of water in body, Electrolyte composition of body fluids and electrolyte balance.

VII. Teaching Methods and Activities

- Lectures
- Assignment (Reading/Writing)

- Group discussion
- Student presentation

VIII. Learning Outcome

Completion of this course will help the students to:

- Acquire advanced knowledge in macro and micronutrients
- Understand specific nutrient related situations in population
- Apply the techniques as per the demand of the human nutritional profile.
- Utilize the learning techniques in population education/publication

IX. Suggested Reading

- Bamji MS, Rao NP and Reddy V. 2003. Textbook of Human Nutrition. 2nd Edition, OXford and IBH Publishing Co. Pvt. Ltd. New Delhi.
- Berdanier CD and Zempleni J. 2009. Advanced Nutrition: Macronutrients, Micronutrients and Metabolism. CRC Press, New York.
- Eastwood MA. 1997. Principles of Human Nutrition. London; Chapman & Hall.
- FAO. 2004. Human Energy Requirements - Report of a Joint FAO/WHO/UNU Expert Consultation. Technical Report Series 1. Food and Agriculture Organization, Geneva.
- FAO. 2007. Protein and Amino Acid Requirements - Report of a Joint FAO/WHO/UNU Expert Consultation. Technical Report Series 1. Food and Agriculture Organization, Rome.
- Groff JL and Gropper S. 2012. Advanced Nutrition and Human Metabolism. 7th Edition, Yolanda Cossio, New York.
- Ross AC, Caballero B, Cousins RJ, Tucker KL and Ziegler TR. 2012. Modern Nutrition in Health and Disease. 11thEdition, LWW, Philadelphia.
- Summathi S. 2017. Food Chemistry and Nutrition. BS Publication, Hyderabad.
- Whitney EN and Rolfels CR. 2019. Understanding Nutrition. 15th Ed., West Publishing Company, USA.
- Wildman REC and Medeiros DM. 2000. Advanced Human Nutrition. CRC Press, Boca Raton, Florida.
- Stipanuk MH and Caudill MA. 2013. Biochemical, Physiological and Molecular Aspects of Human Nutrition. 3rd Edition, Elsevier Pub.
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- http://www.nin.res.in

Weekly Lecture Schedule

Duration (week)	Topic
1	Body composition. Functions, sources, requirements, digestion and absorption of carbohydrates.
2	Composition, classification and functions of dietary fibre.
3	Role of dietary fibre, resistant starch and fructo-oligosaccharides in various physiological disorders. Glycemic response to carbohydrates.
4	Classification, functions, sources, digestion and absorption of proteins.
5	Synthesis of non-essential amino acids in the body. Urea cycle.
6	Protein quality.

7 Classification, functions, sources, digestion, absorption and deficiency disorders of lipids and essential fatty acids.

8 Role of omega-3 fatty acids in physiological disorders.

9 Relationship between energy and protein requirements. Regulation of food intake. Nutrient adaptation to low intake of energy and protein.

10. Functions, absorption, requirement, sources, deficiency and toxicity of fat-soluble vitamins - A, D, E and K.

11. Functions, absorption, requirement, sources, deficiency and toxicity of water- soluble vitamins-thiamine, riboflavin, niacin.

12. Functions, absorption, requirement, sources, deficiency and toxicity of water- soluble vitamins-pyridoxine, folate, B12.

13. Functions, absorption, requirement, sources, deficiency and toxicity of water- soluble vitamins-ascorbic acid, pantothenic acid and biotin.

14. Functions, absorption, requirement, sources, deficiency and toxicity of macro minerals – calcium and phosphorus.

15. Functions, absorption, requirement, sources, deficiency and toxicity of micro minerals – iron, zinc, sodium, copper, cobalt, selenium and chromium.

16. Water and electrolyte balance, functions and distribution of water in body, Electrolyte composition of body fluids and electrolyte balance.

I. Course Title : Public Health and Nutrition

II. Course Code : FN 502

III. Credit Hours : 3(2+1)

IV. Rationale

This core course on public health nutrition will enable the students with the knowledge in assessment of prevailing nutritional situations of a community across age- sex- physiological conditions. Furthermore, opportunities in analysing Public Health consequences in in-situ conditions will empower the students in planning, executing and evaluating the health and nutrition related development schemes of GOs, NGOs and allied bodies to suggest remedial pathways.

V. Aim of the course

- To provide both theory and practical exposure to the students on the subject of Public Health Nutrition
- To make them skilled in management of adequate nutritional statures of the population conducive to National Development.

VI. Theory

Unit I: Nutritional status assessment

Assessment of nutritional status at individual, household and institutional level: direct and indirect methods; Ecological, socio-cultural, economic and demographic correlations of malnutrition.

Unit II: Nutritional deficiencies and life style disorders

Prevalence, aetiology, biochemical and metabolic changes in protein energy malnutrition, vitamin A deficiency, iron deficiency anaemia, iodine deficiency disorders, diabetes mellitus, cancer, hypertension and other life style disorders.

Unit III: Present scenario of nutritional problems

Major nutritional problems of the state, nation and world; Nutrition intervention- definition, importance, methods of nutrition intervention, monitoring and evaluation; E-surveillance.

Unit IV: Nutritional programmes and polices

National nutritional programmes and policies and nutritional surveillance; National programmes and policies regarding food production and distribution.

VII. Practicals

1-3. Techniques of assessment of nutritional status
4-5. Use of Screening Tools
6-7. Visit to the ongoing public health nutrition programme and report writing.
8-9. Study of existing diet and nutrition practices
10-12. Planning and conducting survey
13-14. Analysing data and writing report
15-16. Development, implementation and evaluation of community nutrition and health programmes

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- On field case identification and analysis
- Project planning and report writing

IX. Learning Outcome

Completion of this course will enable the students to take responsibilities as:

- Nutrition educator
- Health educator
- Extension worker for situational analysis of prevailing public health nutritional problems for cultural adaptation strategies.
- Planner and executor of developmental schemes
- Applied researcher

X. Suggested Reading

- Bamji MS, Kamala K and Brhmam GNV. 2017. Textbook of Human Nutrition. 4th Edition, Oxford & IBH.
- Endres JB. 1990. Community Nutrition Challenges and Opportunities. Pearson Education Inc. London.
- Frank GC. 2008. Nutrition: Applying Epidemiology to Contemporary Practice . 2nd Edition, Jonts and Bartlett Publishers, Sadbury, MA.
- Gopaldas T and Seshadari S. 1987. Nutrition Monitoring and Assessment. OXford University Press.

- Jeannette BE. 1990. Community Nutrition: Challenges and Opportunities. 1st Edition, Merrill.
- Jelliffe DB. 1966. The Assessment of the Nutritional Status of the Community. WHO, Geneva.
- Longwah T, Ananthan R, Bhaskarachary K and Venkalah K. 2017. Indian Food Composition Tables. National Institute of Nutrition, Hyderabad.
- Marie AB and David HH. 2012. Community Nutrition in Action: An Entrepreneurial Approach, engage Learning Inc. USA.
- McLaren DS. 1977. Nutrition in the Community. John Wiley & Sons.
- Park JE and Park K. 2007. Park's Text Book of Preventive and Social Medicine. 19th Edition, Banarsidas Bhanot Publishers, Jabalpur.
- Park JE and Park K. 2014. Park's Textbook of Preventive and Social Medicine, Banarsidas Bhano Publ.
- Prabha B. 2017. Community Nutrition in India. 1st Edition, Star Publications, Agra.
- Rosalind S Gibson. 2005. Principles of Nutritional Assessment. 2ndEdition, Oxford University Press Inc.
- Salil S and Rita SR. 2007. Textbook of Community Nutrition. ICAR publication, New Delhi.
- Shukla PK. 1982. Nutritional Problems of India. Prentice Hall of India.
- Suryatapa Das. 2018. Textbook of Community Nutrition. 3rd Edn., Academic Publishers.
- https://www.india.gov.in/
- agriculture
- https://mhrd.gov.in/mid-day-meal
- https://www.harvestplus.org
- https://www.icmr.nic.in/

Weekly Lecture Schedule

Duration (week)	Topic
1	Assessment of nutritional status at individual, household and institutional level: direct and indirect methods.
2	Ecological, socio-cultural, economic and demographic correlations of malnutrition.
3	Prevalence, etiology, biochemical and metabolic changes in Vitamin A deficiency.
4	Prevalence, etiology, biochemical and metabolic changes in Protein Energy Malnutrition.
5	Prevalence, etiology, biochemical and metabolic changes in Iron Deficiency Anaemia.
6	Prevalence, etiology, biochemical and metabolic changes in Iodine Deficiency Disorders.
7	Prevalence, etiology, biochemical and metabolic changes in Diabetes Mellitus.
8	Prevalence, etiology, biochemical and metabolic changes in Hypertension.
9	Prevalence, etiology, biochemical and metabolic changes in Cancer and other life style disorders.
10	Major nutritional problems of the state, nation and world.
11	Nutrition intervention- definition, importance, methods of nutritional intervention, monitoring and evaluation.
12	Methods of nutritional intervention, monitoring and evaluation.
13	E-surveillance.
14	National nutritional programmes and policies and nutritional surveillance.
15	National programmes and policies regarding food production.
16	National programmes and policies regarding food distribution.

I. Course Title : Techniques in Food Analysis

II. Course Code : FN 503

III. Credit Hours : 3 (1+2)

IV. Rationale

Food analysis is the discipline that deals with the development, application and study of analytical procedures for characterizing the properties of foods and their constituents. It provides analytical data on the quality of a food or product.

V. Aim of the course

- To provide the students an opportunity to develop precision with the principles, techniques and application of different methods analysis for varied food and products.
- To equip the students with knowledge to ascertain quality of the tested food/products.

VI. Theory

Unit I: Sampling techniques

Preparation of various standard solutions; Sample and sampling techniques; Introduction to standard analytical methods of FSSAI.

Unit II: Analytical techniques

Principle, techniques and applications of colorimeter, spectrophotometer and atomic absorption spectrophotometer, gel filtration and ultra-centrifugation.

Unit III: Photometric methods and electrophoresis

Principle, techniques and applications of fluorimetry, flame photometry and electrophoresis.

Unit IV: Chromatography

Principle, techniques and applications of paper, thin layer, gas liquid and high- pressure liquid chromatography, introduction to animal assay.

VII. Practicals

1-2. Principles and operation of laboratory equipmen
3-6. Determination of moisture content and titratable acidity
7-8. Determination of ash- dry and wet ash
9-10. Determination of reducing sugars and total sugars
11-14. Analysis of protein- Kjeldhal method
15-16. Analysis of amino acids- HPLC
17-20. Analysis of fat - Soxhlet method, Cold extraction method
21-22. Determination of peroxide value and iodine value
23-24. Analysis of crude fibre. Analysis of minerals- sodium and potassium
25-26. Analysis of iron, copper, zinc and lead. Absorption spectrophotometry
27-28. Analysis of phosphorus- Colorimeter method
29-30. Analysis of vitamin C
31-32. Estimation of carotene. Experiments on gel electrophoresis

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Group activities
- Hands on training

IX. Learning Outcome

- Successful completion of this course will enable the students to:
- Utilize the methods and tools to cater the needs of food analysis
- Guide the process of quality control
- Act as trained food analyst

X. Suggested Reading

- AOAC. 1995. Association of Official Analytical Chemists. Washington, DC. Gruenwedels DW and Whitakor JR. 1984. FoodAnalysis: Principles and Techniques. Vols. I-VIII. Marcel Dekker.
- AOAC International. 2016. AOAC Official Methods of Analysis. 20th Edition, Association of Official Analytical Chemists. Washington DC.
- Dennis D Miller. 1998. Food Chemistry: A Laboratory Manual. John Wiley and Sons Indianapois.
- Joslyn MA. 1970. Methods in Food Analysis: Physical, Chemical and Instrumental Methods of Analysis. Academic Press.
- Kalia M. 2002. Food Analysis and Quality Control. Kalyani Publishers, New Delhi.
- Neilsen SS. 2010. Food Analysis. 4th Ed., ISBN 978-1-4419-1478-1 Springer Science+ Business Media, LLC, USA.
- Neilsen SS. 2002. Introduction to Chemical Analysis of Foods. 1st Ed., J S Offset Printers, Delhi.
- Raghuramulu N, Mahavan and Kalyanasundaram SK. 2003. A Manual of Laboratory Techniques. 2nd Edition, NIN Press, Hyderabad.
- Sadasivam A and Manickam A. 2004. Biochemical Methods. 2nd Edition, New Age International Publishers, New Delhi.
- Sawhney SK and Singh R. 2000. Introductory Practical Biochemistry. Narosa Publishing House, New Delhi.
- Veerakumar L. 2006. Bio-instrumentation. MIP Publishers. Chennai.
- Pomeranz Y and Molean CE. 1977. Food Analysis Theory and Practice. AVI Publ.
- Wood R, Foster L, Damand A and Key P. 2004. Analytical Methods for Food Additives. CRC Press, London.
- https://www.fssai.gov.in
- http://www.fda.gov/food/default.htm

Weekly Lecture Schedule

Duration (week)	Topic
1	Preparation of various standard solutions.
2	Sample and sampling techniques.
3	Sample and sampling techniques.

4 Introduction to standard analytical methods of FSSAI.
5 Principle, techniques and applications of colorimeter.
6 Principle, techniques and applications of spectrophotometer.
7 Principle, techniques and applications of atomic absorption spectrophotometer.
8 Principle, techniques and applications of gel filtration.
9 Principle, techniques and applications of ultra-centrifugation.
10 Principle, techniques and applications of fluorimetry.
11 Principle, techniques and applications of flame photometry.
12 Principle, techniques and applications of electrophoresis.
13 Principle, techniques and applications of paper and thin layer chromatography.
14 Principle, techniques and applications of gas liquid chromatography.
15 Principle, techniques and applications of high-pressure liquid chromatography.
16 Introduction to animal assay.

I. Course Title : Diet Therapy

II. Course Code : FN 504

III. Credit Hours : 3 (2+1)

IV. Rationale

Dietetics is a science and art that deals with the optimum nutrition during normal life cycles and its adaptations during ailments. In any situation of life, optimum nutrition can ensure health, endurance, cognition and productivity. As educators/ advisors, the professionals need to equip themselves with the knowledge and skills of managing foods particularly during illness as people's mental condition remains at low ebb in ailment.

V. Aim of the Course

- To provide both theory and practical knowledge on disease management through appropriate approaches with the most recent scientific input from researchers.
- To approach the subject from a multidisciplinary perspective - technical, psycho- social-economic of client, drug diet interaction, etc, enabling the students to become effective member Health Care Team (HCT) in Medical Nutrition Therapy (MNT).

VI. Theory

Unit I: Significance of diet therapy

Importance and scope of diet therapy; Role of dietician in a health care team in hospital and community.

Unit II: Dietary management of nutritional disorders

Newer concepts in dietary management of various nutritional disorders and disease conditions; fevers and infections.

Unit III: Dietary management of diseases

Dietary management during burns, allergy, gastrointestinal disorders, liver diseases, cardiovascular diseases, hypertension, renal disorders, obesity, diabetes, cancer and HIV; Nutrition in critical care.

Unit IV: Nutrigenomics and nutraceuticals

Nutrigenomics. Nutraceuticals. Health foods and supplements; Health foods and supplements; Dietary recommendations for blood donors; Nutrients and drug interaction.

VII. Practicals

1. Formulation of food exchanges
2. Therapeutic modifications of diet in terms of nutrients, consistency and composition
3. Planning and preparation of diet for diabetes

4-5. Planning and preparation of diet for cardiovascular diseases

6-7. Planning and preparation of diet for kidney disorders

8. Planning and preparation of diet for obesity
9. Planning and preparation of diet for cancer patients
10. Planning and preparation of diet for burns patients -first, second and third-degree burns

11-12. Planning and preparation of diet for gastrointestinal disorders

13. Planning of diet for critical care patients
14. Visits to hospital to see preparation of tube feeding diets

15-16. Presentation of case studies

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- Case studies
- Hands on training

IX. Learning Outcome

After completion of this course, the students are eXpected to:

- Appreciate the scientific foundation of disease management through diet
- Utilize the techniques and tools for assessing the vulnerability of a disease situation towards rejection/ acceptance of the diet suggestion
- Confident responsible member of Healthcare team (HCT) as decision maker

X. Suggested Reading

- Cataldo CB, De Brayae LK and Whitney EN. 2012. Nutrition and Diet Therapy. 6th Edn.,Wadsworth/Thomson Learning Inc.
- Kathleen ML and JL Raymond. 2016. Krause's Food and the Nutrition Care Process. 14th Edition, Saunders, Philadelphia.
- Mazur EE and Litch NA. 2018. Lutz's Nutrition and Diet Therapy. 7th Edition, F.A. Davis Company, Philadelphia.
- McIntosh SN. 2016. Williams' Basic Nutrition and Diet Therapy. 15th Edition, Mosby, Maryland.
- Schlenker E and Gilbert JA. 2014. Williams' Essentials of Nutrition and Diet Therapy. 11th edition, e- book

- Srilakshmi B. 2019. Dietetics. 8th Edition, New Age Internatioanal Publisher.
- Skipper A. 2008. Advanced Medical Nutrition Therapy Practice. 1st Edition, Jones & Bartlett Learning, Burlington, Massachusetts.
- Ross AC, Caballero B, Cousins RJ, Tucker KL and Ziegler TR. 2012. Modern Nutrition in Health and Disease. 11th Edition, LWW, Philadelphia.
- Whitney E, DeBruyne LK, Pinna K and Rolfes SR. 2011. Nutrition for Health and Health Care. 4th Edition.
- https://www.nutritionintl.org
- https://www.hsph.harvard.edu/nutritionsource
- https://www.nutrition.org.uk
- http://www.nutritioncare.org

Weekly Lecture Schedule

Duration (week)	Topic
1.	New concepts in dietary management of various disorders and diseases, protocols for dietary management.
2.	Importance and scope of diet therapy. Role of dietician in a health care team in hospital and community.
3.	Newer concepts in dietary management of fevers and infections.
4.	Dietary management during burns and allergies.
5.	Dietary management during gastrointestinal disorders.
6.	Dietary management during liver diseases.
7.	Dietary management during obesity.
8.	Dietary management during hypertension and cardiovascular diseases.
9.	Dietary management during diabetes.
10.	Dietary management during renal disorders.
11.	Dietary management cancer and HIV.
12.	Nutrition in critical care.
13.	Nutrigenomics and nutraceuticals.
14.	Health foods and supplements.
15.	Dietary recommendations for blood donors.
16.	Nutrients and drug interaction.

I. Course Title : Nutrition and Physical Fitness

II. Course Code : FN 505

III. Credit Hours : 3 (2+1)

IV. Rationale

Physical fitness is a state of health and well-being and more particularly, the capacity to perform satisfactorily in occupations, daily chores and sports. It is generally achieved through proper nutrition, physical exercise and rest. Physical fitness is considered as a measure of body's ability to function efficiently and effectively in work and leisure activities, to be healthy and to resist diseases and to meet emergency situations.

V. Aim of the course

- To provide both theory and practical exposure to understand the concept of physical fitness
- To incorporate recent techniques of body composition and energy metabolism to ascertain the nutritional stature
- To equip the students with the knowledge and capacity to identify, evaluate and evolve ways in addressing various aspects of physical fitness.

VI. Theory

Unit I: Physical fitness and body composition

Overview of nutritional management vis-à-vis body composition and physical fitness; Techniques to assess physical fitness; Body composition in different physiological conditions and factors affecting it; Methods of measuring body composition.

Unit II: Energy balance

Energy metabolism; Factors influencing energy metabolism and physical fitness; Techniques to measure energy expenditure and energy intake.

Unit III: Sports nutrition

Requirement of nutrients for specific sports events; Exercise physiology and biochemistry; Nutrition support before, during and after sports event; Water and electrolyte requirement during exercise and their role in performance; Ergogenic aids; Definition, types and dosage; Doping: Definition, types and consequences; Muscle physiology for performance and fitness; Biomechanics; Physiological testingfor fitness and performance; Strength, respiratory fitness.

Unit IV: Nutrition and ageing

Role of nutraceuticals in fitness; Ageing theories; Physiology, mechanism and role of nutrients in arresting ageing process.

VII. Practicals

1-4. Planning diets for general fitness
5-12. Planning and preparation of diets for different sports categories
13-14. Planning nutritional requirements for sports injuries
15. Visit to a sports academy
16. Visit to established fitness centres

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Writing/Reading)
- Student presentation
- Group activities
- Case studies
- Hands on training

IX. Learning Outcome

On completion of this course, the students will be able to handle responsibilities as:

- Physical fitness educator/ Adviser
- Utilize methods and techniques for vulnerability assessment as per need of the situation
- Experts in Healthcare Team and fitness centres

X. Suggested Reading

- Benardot D. 2005. Advanced Sports Nutrition. 2nd Edition, Human Kinetics Publishers, Champaign, IL.
- Baumgartner R. 2006. Body Composition in Healthy Aging. Annals of the New York Academy of Sciences.
- FAO. 2004. Human Energy Requirements. -Report of a Joint FAO/WHO/UNU Expert Consultation. Technical Report Series 1. Food and Agriculture Organization, Geneva.
- Geetanjali B and Subhadra M. 2018. Nutritional Guidelines for Sportspersons. Jaypee Health Books Publishers.
- Geissler C and Powers H. 2009. Fundamentals of Human Nutrition. Churchill Livingstone, London.
- Ross AC, Caballero B, Cousins RJ, Tucker KL and Ziegler TR. 2012. Modern Nutrition in Health and Disease. Eleventh Edition, LWW, Philadelphia.
- Srilakshmi B, Suganthi V and Kalaivani C Ashok. 2017. Exercise Physiology Fitness and Sports Nutrition. New Age International Publishers.
- https://www.who.int
- https://www.hsph.harvard.edu/nutritionsource
- http://www.nutritioncare.org

Weekly Lecture Schedule

Duration (week)	Topic
1	Concept of physical fitness, recent techniques of body composition and energy metabolism.
2	Overview of nutritional management vis-à-vis body composition and physical fitness.
3	Methods of measuring body composition.
4	Body composition in different physiological conditions and factors affecting it.
5	Techniques to assess physical fitness.
6	Energy metabolism. Factors influencing energy metabolism and physical fitness.
7	Techniques to measure energy expenditure and energy intake.
8	Requirement of nutrients for specific sports events.
9	Exercise physiology and biochemistry.
10	Nutrition support before, during and after sports event.
11	Water and electrolyte requirement during exercise and their role in performance.
12	Ergogenic aids: Definition, types and dosage.
13	Doping: Definition, types and consequences. Muscle physiology for performance and fitness.
14	Biomechanics. Physiologic testing for fitness and performance.
15	Strength, flexibility, anaerobic power and cardio respiratory fitness Role of nutraceuticals in fitness.
16	Ageing theories Physiology, mechanism and role of nutrients in arresting ageing process

I. **Course Title : Developments in Nutrition and Immunity**

II. **Course Code : FN 506**

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

IV. Rationale

Immunity is the capability of multi-cellular organism to resist harmful microorganisms from entering it. Good nutrition is essential to build a strong immune system which offers protection from seasonal illness (flu, cold) and other health problems (arthritis, allergies, abnormal cell development, etc.) Students with a good knowledge about role of nutrition in boosting a strong immune system in population will be able to reduce risk factors arising of malnutrition and infection.

V. Aim of the course

- To impart knowledge about role of various macro and micronutrients along with prebiotics, probiotics and phytochemicals in improving immune systems in the population
- To induce understanding about nutrition and immunity in disease management in age- seX groups across all physiological stages.

VI. Theory

Unit I: Immunity and macronutrients

Immunity: definition and history; Classification of immunity and immunological responses; Role of nutrients in immune functions- Carbohydrates, fat and protein; Effect of arginine, glutamine, sulphur amino acids and omega-3 fatty acids on immune system.

Unit II: Immunity and micronutrients

Effect of deficiency and excess of vitamins and minerals on immune cell functions; Effect of malnutrition on immunity; Infections and undernutrition – causes and consequences and role of immunization.

Unit III: Nutrition during infections

Age related immune depression; Role of nutraceuticals and functional foods in immune system; Nutrition, HIV/AIDS and Tuberculosis.

Unit IV: Immunity and chronic diseases

Nutritional immunity and chronic diseases; Probiotics, prebiotics, phytochemicals and immunity; Food allergy.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Written/Reading)
- Students' presentations
- Group discussion

VIII. Learning Outcome

Completion of the course will enable the students to:

- Understand underlying causes of poor immune system

- Appreciate the scientific foundation for better management of risks associated with poor nutrition and immunity
- Act as confident members in healthcare teams
- Utilize information for publication/ education

IX. Suggested Reading

- Calder P and Yaqoob P. 2013. Diet, Immunity and Inflammation. Woodhead Publishing Ltd. Cambridge.
- Gershwin ME, German JB and Keen CL. 2000. Nutrition and Immunology – Principles and Practice. Humana Press Inc. New York.
- Gershwin ME, Nestel P and Keen CL. 2004. Handbook of Nutrition and Immunity. Humana Press Inc. New York.
- Ivan M Roitt and Peter J Deves. 2004. Essential Immunology. Blackwell Science Ltd
- Pammi M, Vallejo JG and Abrams SA. 2016. Nutrition-Infection Interactions and Impacts on Human Health. CRC Press, Boca Raton, Florida.
- Philip C Calder and Anil D Kulkarni. 2017. Nutrition, Immunity, and Infection. CRC press, London
- Shetty PS. 2010. Nutrition, Immunity and Infection. CABI Publishers, OXfordshire, UK.
- https://www.nutritionintl.org
- https://nutrition.org
- https://www.icmr.nic.in

Weekly Lecture Schedule

Duration (week)	Topic
1	Role of nutrients in maintaining and improving the immunity of individuals.
2	Immunity: definition, history and classification of immunity and immunological responses.
3	Role of nutrients in immune functions- Carbohydrates, fats and proteins.
4	Effect of arginine, glutamine, sulphur amino acids and omega-3 fatty acids on immune system.
5	Effect of deficiency and excess of vitamins and minerals on immune cell functions.
6	Effect of malnutrition on immunity.
7	Infections and undernutrition.
8	Causes and consequences and role of immunization.
9	Age related immune depression.
10	Role of nutraceuticals and functional foods in immune system.
11	Nutrition in HIV/AIDS.
12	Nutrition in Tuberculosis.
13	Nutrition, immunity and chronic diseases.
14	Probiotics, prebiotics and immunity.
15	Phytochemicals and immunity.
16	Food allergy.

I. Course Title : Clinical Nutrition

II. Course Code : FN 507

III. Credit Hours : 3 (2+1)

IV. Rationale

Clinical nutrition is nutrition of patients in Health care and refers to the management of patients. It incorporates primarily the scientific fields of nutrition and dietetics. Knowledge of striking a positive energy balance in patients along with providing sufficient amount of other nutrients such as proteins, vitamins, minerals is the basis of patient's Health Care Management.

V. Aim of the course

- To provide both theoretical and applied knowledge on the subject of clinical nutrition for better management of diseases
- To approach various areas of nutrition from a multidisciplinary perspective - biochemical, physiological, pathological and regulatory
- To equip the students to identify the inter-relationship, etiology and management techniques to a specific disease situation including in patients "medical nutrition therapy" understanding to induce situational improvement of health.

VI. Theory

Unit I: Macronutrients

Methods for estimating requirements and recommended allowances of energy, protein, minerals and vitamins for different age groups and physiological state; Growth studies; Depletion and repletion studies; Nutrient balance studies; Use of isotopically labelled nutrients: Nutrient turnover; Obligatory losses of nutrients; National and international recommendations on Nutrient Requirements; Recommendations for Indian by the Indian Council of Medical Research; FAO/ WHO eXpert committee recommendations; Nutrient interrelationship; therapeutic measures of protein energy malnutrition; Adaptation and chronic energy deficiency; Regulatory processes in chronic energy deficiency; Protein and amino acid turnover; Regulation of amino acid metabolism; Disposal of dietary amino acids and roles of specific organs.

Unit II: Micronutrients

Interrelationship, etiology and preventive measures of vitamin and mineral deficiencies toxicities; Adverse effects of Vitamins and minerals; Upper tolerable levels; Principles and interpretation of clinical laboratory methods with particular emphasis on their interpretation relative to nutritional status and disease; interaction between nutrients, infections and drugs; Functional tests of malnutrition; Nutritional assessment tools in clinical decision making.

Unit III: Nutritional support during disease

Nutritional support, enteral tube feeding, parenteral nutrition, drugs and enteral feeding; Special considerations with nutritional support; Nutrition in surgery and trauma; The stress response to trauma on metabolism; Nutrition support in critically ill patient; Guidelines for use of formula feeds and calculation.

Unit IV: Therapeutic nutrition

Nutrition in GI Diseases; Celiac disease, inflammatory bowel disease, Assessment of liver function - nutritional management in liver disease, acute and chronic pancreatitis, severity scores, nutritional aspects of disease affecting the skeleton, diagnostic imaging, biochemical assessment; Acute and chronic renal failure, nephrotic syndrome, transplantation; Diet and hypertension, stroke, peripheral vascular disease, and chronic heart failure; Wasting syndrome in cancer; Impact of radiation and chemotherapies; Nutritional support on clinical outcomes.

VII. Practicals

1-4. Visit to critical care wards in hospitals for familiarizing with enteral and parenteral feeding methods.

5. Handling and deciphering the medical case sheets.

6-9. Planning enteral feeding, critical care nutritional requirements for different clinical conditions

10-11. Calculating energy, protein, fat and micronutrients after nutritional assessment.

12-13. Presenting case studies of medical cases

14-15. Survey of various enteral feed formulations for different clinical conditions

16. Report writing

VIII. Teaching Methods/Activities

- Lectures
- Assignment (writing/reading)
- Students' presentation
- Group activities
- Case studies in medical setup.
- Hands on training

IX. Learning Outcome

After successful completion of this course, the students will be able to

- Appreciate scientific understanding of the clinical situation of a patient and suggesting complementary nutrition therapy for its management
- Utilize methods and tools related to nutrition assessment and advocacy strategies along with Health Care Team
- Utilize knowledge for scientific Publication
- "Care Education" for target groups
- Utilize the knowledge to act as technical expert in R&D projects

X. Suggested Reading

- Connie WB and Christine SR. 2016. Handbook of Clinical Nutrition and Ageing. Humana Press.
- FAO. 2004. Human Energy Requirements - Report of a Joint FAO/WHO/UNU ExpertConsultation. Technical Report Series 1. Food and Agriculture Organization, Geneva.
- Gibney MJ, Macdonald IA and Roche HM. 2011. Nutrition and Metabolism. Wiley-Blackwell Publishing Company, Boston.
- Gibney MJ, Elia M, Ljungqvist O and Dowsett J. 2013. Clinical Nutrition. Wiley-Blackwell Publishing Company, Boston.
- Heimburger DC and Ard JD (2006) Hand Book of Clinical Nutrition. Mosby Pub.
- Joshi YK. 2009. Basics of Clinical Nutrition. 2nd Edition, Jaypee Brothers Medical Publishers Private Limited, New Delhi.
- Macdonald IA and Michael J Gibney MJ. 2011. Nutrition and Metabolism. Wiley-Blackwell Publishing Company, Boston.

- Narasinga Rao BS and Sivakumar B. 2010. Nutrient Requirements and Recommended Dietary Allowances. 2nd Edition, National Institute of Nutrition, Hyderabad.
- Marian M and Susan R. 2009. Clinical/Nutrition for Oncology Patients. Jones and Bartlett Pub.
- Scott AS and George LB. 1997. Nutrition Support-Theory and Therapeutics. Chapman and Hall Series, International Thomson Publications.
- Sharon RR , Kathryn P and Whitney E. 2017. Understanding Normal and Clinical Nutrition. Cengage Learning.
- Width M and Reinhard T. 2017. The Essential Pocket Guide for Clinical Nutrition. LWW Pub.
- Vishwanath S. 2017. Introduction to Clinical Nutrition. CRC Press.
- http://www.nutritioncare.org
- https://nutrition.org
- http://www.nutritionlink.org/

Weekly Lecture Schedule

Duration (weeks) Topic

1. Methods for estimating requirements and recommended allowances of energy, protein, minerals and vitamins for different age groups and physiological state.
2. Growth studies. Depletion and repletion studies. Nutrient balance studies.
3. Use of isotopically labelled nutrients: Nutrient turnover. Obligatory losses of nutrients.
4. National and international recommendations on nutrient requirements. Recommendations for Indian by the Indian Council of Medical Research. FAO/ WHO expert committee recommendations.
5. Nutrient interrelationship; therapeutic measures of protein energy malnutrition. Adaptation and chronic energy deficiency. Regulatory processes in chronic energy deficiency.
6. Protein and amino acid turnover. Regulation of amino acid metabolism. Disposal of dietary amino acids and roles of specific organs.
7. Interrelationship, etiology and preventive measures of vitamin and mineral deficiencies toXicities. Adverse effects of vitamins and minerals. Upper tolerable levels.
8. Principles and interpretation of clinical laboratory methods with particular emphasis on their interpretation relative to nutritional status and disease; interaction between nutrients, infections and drugs.
9. Functional tests of malnutrition. Nutritional assessment tools in clinical decision making.
10. Nutritional Support, Enteral tube feeding, Parenteral nutrition, drugs and enteral feeding.
11. Special considerations with nutritional support, Nutrition in surgery and trauma. The stress response to trauma on metabolism.
12. Nutrition support in critically ill patient. Guidelines for use of Formula feeds and calculation.
13. Nutrition in GI Diseases, celiac disease and inflammatory bowel disease. Assessment of liver function-nutritional management in liver disease, acute and chronic pancreatitis, Severity scores.
14. Nutritional aspects of disease affecting the skeleton. Diagnostic imaging, biochemical assessment. The Kidney- Acute, chronic renal failure, Nephrotic syndrome, transplantation.
15. Diet and hypertension, stroke, peripheral vascular disease and chronic heart failure.
16. Wasting syndrome in cancer. Impact of radiation and chemotherapies. Nutritional support on clinical outcomes.

I. Course Title : Nutrition Counselling

II. Course Code : FN 508

III. Credit Hours : 2 (0+2)

IV. Rationale

Nutrition counselling is an ongoing process in which nutrition professional works with an individual to assess his/her usual dietary intake to support growth, development and maintenance conducive to good health in normal and ailing conditions. As counsellor, it requires high skill in communication, subject knowledge and understanding the client's socio-eco- cultural background to offer curative/ preventive nutritional advice.

V. Aim of the course

- To provide ample hands on training to develop skills in communication, application of subject knowledge and understanding client's need and offer curative/ preventing dietary plan in medical or non-medical set-ups
- Tol approach the counselling techniques from and multidimensional perspective i.e. personal, medical, socio-eco cultural good habits and causative factors that contribute to the development of situations affecting normal health of population
- To create effective nutrition counsellors for addressing health and nutritional challenges of population.

VI. Practicals

1-2. Development of resources and dietary guidelines for counselling

3-4. Procedures of nutritional counselling in clinical practice

5-12. Preparing nutritional and dietary care plans for individuals and groups

13-16. Records required for follow up study, group discussion and motivation as tools to bring attitudinal changes in food selection and preparation

17-18. Exercises on writing scientific facts in simple manner for the people

19-22. Diet campaigns, exhibitions, demonstrations and workshops

23-28. Setting up counselling unit. Counselling in outpatient wards in local hospitals

29-30. Simulation techniques for counselling in selected settings

31-32. Use of dietary apps for counselling and assessing food intake

VII. Teaching Methods/ Assignments

- Hands on training
- Group activities
- Project planning and report writing
- Case studies

VIII. Learning Outcome

After successful completion of this practical course, students will be able to:

- Act as confident nutrition counsellor in given setup
- Utilize methods and techniques to correct nutrition related health problems and suggest adaptive strategies in the conteXt of social milieu

- Utilize the scientific knowledge for benefit of the community through population education/ publication
- Act as resource person in handling R&D projects

IX. Suggested Reading

- Aronson V. 1989. The Dietetic Technician-Effective Nutrition Counselling. John Wiley and Sons Florida.
- Betsy H and Judith BA, 2014. Nutrition Counselling and Education Skills for Dietetics Professional. 6th Edition, LWW, Philadelphia.
- Devito JA. 2015. Human Communication: The Basic Course. Pearson, New York.
- Gable J. 2016. Counselling Skills for Dietitians. John Wiley and Sons Florida.
- Kathleen DB, Doreen Land Carol AS. 2001. Basic Nutrition Counselling Skill Development. Brooks Cole Pub.
- Kathleen DB, Doreen L and Carol AS. 2014. Nutrition Counselling and Education Skill Development. CENGAGE Learning Custom Pub, USA.
- King K and Klawitter B. 2007. Nutrition Therapy. Advanced Counselling Skills. 3rd Edition, LWW, Philadelphia.
- Mahan LK and Escott S. 2016. Krause's Food & Nutrition Therapy. 14th Edition, Saunders, Philadelphia.
- Midwinter R and Dickson J. 2015. Embedding Counselling and Communication Skills - A Relational Skills Model. Routledge.
- Snetselaar L. 2009. Nutrition Counselling Skills for the Nutrition Care Process. 4th Edition Jones Bartlett Publishers, Sudbury, Massachusetts.
- https://nutrition.org
- http://www.nutritionlink.org
- http://www.fao.org/docrep/X2550E/X2550e04.htm

I. Course Title : Food Safety And Standards

II. Course Code : FN 509

III. Credit Hours : 3 (2+1)

IV. Rationale

Food safety involves the prevention of the adverse effects of chemical substances of food on human beings and means to overcome toxic effect through appropriate processing techniques. It is important to derive maximum benefits of consumed food as far as practicable toxin free.

V. Aim of the course

- To provide both theoretical and practical exposure to the students on the subject of food safety including types of toxin and methods of removal of these in terms of human health
- To approach the related topics ranging from types, causative factors, signs and symptoms of food toxicity, removal and potential containments
- To induce sufficient knowledge regarding national and international food safety standards.

VI. Theory

Unit I: Xenobiotics

Toxicologically relevant principles of the cell and molecular biology; Dynamics and kinetics of xenobiotics; Environmental pollutants entering the food chain.

Unit II: Food poisoning

Introduction and significance of food toxicology; Food poisoning – types, causative factors, signs and symptoms and preventive measures; Naturally occurring food toxins, their harmful effects and methods of removal.

Unit III: Microbial and chemical toxins

Microbial toxins and food intoxication – source of contamination, effects on health, preventive measures and methods of inactivation and destruction; Chemical toxins – pesticides, insecticides, metallic and others and their residual effects, preventive measures and methods of removal.

Unit IV: Food safety laws and standards

Food packaging material – Potential contaminants from food packaging material; Food safety laws and standards: FSSAI, FPO, ISI, Agmark, Codex Alimentarius, ISO mark for vegetarian and non-vegetarian foods, eco-friendly products and others in operation.

VII. Practicals

1-2. Basic chemical diagnostics of poisonings based on the samples from dead animal's organs and feed

3-7. Methods of identification and quantification of poisons isolation from biological materials

8-9. Principles of sampling and sending biological materials for toxicological analysis

10. Basis of intravital laboratory diagnostics of acute and chronic poisonings

11. Evaluation of toxic effects concerning the degree and the time of exposure to a xenobiotic

12-13. The determination of cholinesterase activity in the whole blood, in blood plasma and in red blood cells after the exposure to organophosphate and carbaminate insecticides

14. Evaluation of the effect of an antidote

15. Identification of nitrite and nitrate in water and in vegetables

16. Evaluation of nitrite and nitrate effect on haemoglobin.

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Group activities
- On field case identification and analysis
- Hands on training

IX. Learning Outcome

Successful completion of this course will enable the students to:

- Be an expert on the subject relating key learnings as food safety officer/ extension worker/ food inspector
- Utilize learning in scientific Publications/ population education

X. Suggested Reading

- Concon JM. 2000. Food Toxicology- Principles and Concepts - Part A and B. Marcel-Dekker Inc. New York.
- Helferich W and Winter CK. 2001. Food Toxicology. CRC Press, Boca Raton, Florida.
- Pussa T. 2013. Principles of Food Toxicology. CRC Press, Boca Raton, Florida.
- Timbrell J. 2001. Introduction to Toxicology. 3rd Edition, Informa, London.
- Vought JB and Henderson MK. 2000. Principles of Sampling and Sending Biological Materials for Toxicological Analysis - Unit II Biomarkers Practical Aspects. IARC publication, WHO, Geneva.
- https://www.fssai.gov.in
- http://www.fda.gov/food/default.htm

Weekly Lecture Schedule

Duration (weeks)	Topic
1	Toxicologically relevant principles of the cell and molecular biology.
2	Dynamics and kinetics of xenobiotics.
3	Environmental pollutants entering the food chain.
4	Introduction and significance of food toxicology.
5	Food poisoning – types and causative factors.
6	Food poisoning- signs and symptoms and preventive measures.
7	Naturally occurring food toxins, their harmful effects.
8	Naturally occurring food toxins- methods of removal.
9	Microbial toxins and food intoxcation – source of contamination and effects on health.
10	Microbial toxins and food intoxication- preventive measures and methods of inactivation and destruction.
11	Chemical toxins – pesticides, insecticides, metallic and others and their residual effects.
12	Chemical toins – Preventive measures and methods of removal.
13	Food packaging material- Potential contaminants from food packaging material.
14	Food laws and standards: FPO and ISI.
15	Agmark, Codex Alimentarius and ISO.
16	Mark for vegetarian and non-vegetarian foods, eco-friendly products and others in operation.

I. Course Title : Nutritional Challenges in Life Cycle

II. Course Code : FN 510

III. Credit Hours : 3 (3+0)

IV. Rationale

Nutrition is crucial for the fulfilment of human rights especially those of the most vulnerable groups i.e. infants, children less than 5 years of age, girls and women who constitute the foundation of human development and national prosperity. Knowing the nutritional challenges during various stages of life cycle can reduce susceptibility to infection, morbidity, disability and mortality, thereby, enhancing cumulative lifelong learning capacities and adult productivity.

V. Aim of the course

- To give an exposure to the students with an in-depth basic knowledge regarding nutritional challenges of vulnerable groups during various stages of life cycle
- To approach the areas from various angles like nutritional needs of fetus, mothers (expectant and lactating), adolescents, adults and geriatrics in terms of cognitive learning abilities and to remain healthy and productive
- To equip students to identify, evaluate and evolve management techniques to address nutritional challenge.

VI. Theory

Unit I: Importance of maternal nutrition

Nutritional needs during first 1000 days; Influence of maternal nutritional status on outcome of pregnancy: birth weight of infant and lactation performance.

Unit II: Human Milk

Psycho-physiology of lactation; Milk synthesis and secretion; Maternal needs during lactation; Composition of colostrum and mature human milk; Milk of mothers of preterm babies; Milk of animal and formula feeds; Non-nutritional factors of human milk - immunological factors, enzymes and hormones; Human milk banking.

Unit III: Nutrition during childhood, adolescence and adulthood

Nutritional needs of the children and adolescents; Common childhood ailments and dietary considerations; Growth spurt and nutrition; Adolescent fads influencing nutrition, food preferences and nutritional problems; Nutritional requirements in adulthood; Malnutrition, mental development, learning abilities and behavior.

Unit IV: Geriatric nutrition

Overview of ageing process; Nutritional variables related to the ageing process; Physiology of aging; Biological markers of aging; Sociology of aging; Nutritional requirements and deficiencies in elderly; Medications and psychiatric problems in elderly; Immunopathological diseases and aging; Parkinson and Alzheimer syndrome; Care of the elderly; Care-givers and community services.

VII. Teaching Methods/ Activities

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

VIII. Learning Outcome

Successful completion of this course will enable the students to

- Appreciate the scientific understanding of mitigating nutritional challenges and relating key learning as professional expert in the area
- Utilize methods and hand tools for vulnerability assessment and designing adaptation strategies
- Utilize knowledge in scientific publication/ population education
- Be an expert in community health and R&D projects

IX. Suggested Reading

- Bales CW, Ritchie CS. 2013. Handbook of Clinical Nutrition and Aging. 2nd Edition, Springer Science & Business Media, Humana Press Inc. New York.
- Cataldo CB, De Brayae LK and Whitney EN. 2012. Nutrition and Diet Therapy. 6th Edn., Wadsworth/Thomson Learning Inc.
- Chernoff R. 2003. Geriatric Nutrition: The Health Professional's Handbook. 2nd Edition, Jones & Bartlett Learning, Burlington, Massachusetts.
- Kleinman RE. 2008. Paediatric Nutrition Handbook. 6th Edition, American Academy of Paediatrics Committee on Nutrition.
- Sachdev HPS and Choudhury P. 2004. Nutrition in Children - Developing Country Concerns. B I Publications.
- Schlenker E and Gilbert JA. 2014. Williams' Essentials of Nutrition and Diet Therapy. 11th Edition, e- book.
- Sharbaugh C and Brown JE. 2013. Nutrition Through the Life Cycle. 5th Edition, Wadsworth Co Inc. Belmont, CA.
- Srilakshmi B. 2019. Dietetics. 8th Edition, New Age Internatioanal Publisher.
- Whitney E, DeBruyne LK, Pinna K and Rolfes SR. 2011. Nutrition for Health and Health Care. 4th Edition.
- World Health Organization. 2005. WHO Library Cataloguing-in-Publication Data. Nutrition in Adolescence –Issues and Challenges for the Health Sector. WHO, Geneva.
- https://www.who.int
- http://www.nutritionlink.org
- https://www.icmr.nic.in

Weekly Schedule

Duration (week)	Topic
1	Nutritional needs of the foetus during different stages of fetal cell growth
2	Maternal nutritional needs
3	Influence of maternal nutritional status on outcome of pregnancy: birth weight of infant and lactation performance.
4	Psycho-physiology of lactation. Milk synthesis and secretion.
5	Maternal needs during lactation.
6	Composition of colostrum and mature human milk. Milk of mothers of preterm babies. Milk of animal and formula feeds.
7	Non-nutritional factors of human milk -immunological factors, enzymes and hormones.
8	Human milk banking.
9	Nutritional needs of the children and adolescents.
10	Common childhood ailments and dietary considerations.
11	Growth spurt and nutrition. Adolescent fads influencing nutrition, food preferences and nutritional problems.
12	Nutritional requirements in adulthood. Malnutrition, mental development, learning abilities and behaviour.
13	Overview of ageing process. Nutritional variables related to the ageing process. Physiology of aging. Biological markers of aging. Sociology of aging.

14 Nutritional requirements and deficiencies in elderly. Medications and psychiatric problems in elderly.

15 Immuno-pathological diseases and aging. Parkinson and Alzheimer syndrome.

16 Care of the elderly. Care-givers and community services.

I. Course Title : Food Science

II. Course Code : FN 511

III. Credit Hours : 3 (2+1)

IV. Rationale

Food is an integral part of everyone's life. This course will empower the students to understand the science factors of food, effects of different processing methods on its nutritional qualities and how to conserve nutrients to the best benefits of the consumers.

V. Aim of the course

- To expose the students in understanding the changes in foods during various processing methods in laboratory setups
- To equip the students in understanding the desirable and undesirable effects of food treatments and identify the best ones for the benefit of consumers as food or trade.

VI. Theory

Unit I: Evaluation of food

Colloidal chemistry as related to foods; Evaluation of food by subjective and objective methods.

Unit II: Characteristics of sugars and starches

Carbohydrates in foods sources; Characteristics of sugar; Starches - types, sources, uses and chemical characteristics; Factors effecting viscosity of starch paste; Characteristics of cellulose and pectin; Gums in foods; Effect of cooking and processing techniques on carbohydrates; Batters and dough- types, properties.

Unit III: Processing of cereals, legumes and animal foods

Preparation of gluten structure; Dough changes in baking; Protein in foods: Plant and animal protein; Chemical and physical properties related to protein foods; Effect of cooking and processing techniques on animal foods – meat, fish, poultry, eggs, milk and milk products; Effect of cooking and processing of plant foods – cereals, millets, legumes, nuts and oilseeds;

Unit IV: Processing of fruits and vegetables

Classification and importance of fruits and vegetables; Composition of fruits and vegetables. Effect of cooking and other processing methods on the nutritive value of fruits and vegetables; Food pigments; Browning reactions in fruits and vegetables; Classification and importance of beverages; Definition, classification, uses and legal aspects of food additives; Classification, nature and uses of leavening agents.

VII. Practicals

1. Microscopic structure of different starch granules
2. Evaluation of food by subjective and objective methods
3-4. Changes in colour, texture and flavour of foods due to processing
5. Product preparation using leavening agents
6. Physicochemical evaluation of grains like length, breadth, L/B ratio, bulk density, cooking properties, 1000 grains weight
7. functional properties of grains - gelatinization, water absorption capacity, oil retention capacity and water retention capacity
8-9. Sugar cookery
10. Smoking temperature of fats and oils
11. Factors effecting absorption of fats
12. Deep fat fried food preparation
13. Changes in cookery- meat, fish, poultry
14. Coagulation of egg, poached egg, omelette, custard, cake
15. Emulsion - mayonnaise preparation
16. Soaking, germination and fermentation of pulses

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- Hand on experience

IX. Learning Outcome

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

- Appreciate the scientific foundation of food and its application to the benefits of human health
- Perform as Food Analyst
- Become Food Entrepreneurs
- Act as Health/ Nutrition advisor

X. Suggested Reading

- Belle Lowe. 2019. Experimental Cookery from the Chemical and Physical Standpoint. Facsimile Pub.
- Potter NN and Hotchkiss JH. 2007. Food Science. 5th Edition, CBS, New Delhi.
- Roday S. 2018. Food Science and Nutrition. 3rd Edition, OXford University Press, UK.
- Sharma A. 2005. Textbook of Food Science and Technology. 3rd Edition, CBS, New Delhi.
- Stone H. 2004. Sensory Evaluation Practices (Food Science and Technology). 3rd Edition, Academic Press, Cambridge.
- Subbalakshmi G and Udipi SA. 2006. Food Processing and Preservation. New Age International, New Delhi.
- Sofia Jan. 2013. Elements of Food Science. New India Publishing Agency,New Delhi ISBN: 979-93-81450-24-6.

- Vaclavik VA and Christian EW. 2014. Essentials of Food Science. 4th Edition, Springer- Verlag, New York.
- https://www.ift.org
- https://www.foodsciencematters
- https://www.ifst.org

Weekly Lecture Schedule

Duration (week)	Topic
1	Colloidal chemistry as related to foods.
2	Evaluation of food by subjective and objective methods.
3	Carbohydrates in foods sources.
4	Characteristics of sugar.
5	Starches-types, sources, uses and chemical characteristics.
6	Factors effecting viscosity of starch paste.
7	Characteristics of cellulose and pectin. Gums in foods.
8	Effect of cooking and processing techniques on carbohydrates. Batters and dough- types, properties.
9	Preparation of gluten structure. Dough changes in baking.
10	Protein in foods: Plant and animal protein. Chemical and physical properties related to protein foods.
11	Effect of cooking and processing techniques in Animal foods – meat, fish, poultry, eggs, milk and milk products.
12	Effect of cooking and processing of plant foods – cereals, legumes, nuts and oilseeds.
13	Classification and importance of fruits and vegetables. Composition of fruits and vegetables.
14	Effect of cooking and other processing methods on the nutritive value of fruits and vegetables. Food pigments. Browning reactions in fruits and vegetables.
15	Classification and importance of beverages. Definition, classification, uses and legal aspects of food additive.
16	Classification, nature and uses of leavening agents.

I. Course Title : Food Processing Technology

II. Course Code : FN 512

III. Credit Hours : 3(2+1)

IV. Rationale

Almost all foods consumed need processing from field to plate. While some processing is applicable to day- to- day life to consume safe and healthy foods, most of the perishable foods require special techniques to conserve nutrients alongside increasing shelf life. Knowledge of the subject is an integral part for food entrepreneurs.

V. Aim of the course

- To give exposure of the subject, with the newer techniques in food processing procedures ranging from preliminary steps to the packaging aspects of different foodstuff for safe consumption and business

- To equip students to identify and application of processing methods suitable to meet the purpose of the consumer.

VI. Theory

Unit I: Food processing techniques

Principles underlying food processing operations including thermal, radiation, refrigeration freezing and dehydration; Effect of processing on physiochemical characteristics; Principles underlying pressure modified processing (high hydrostatic pressure, hyperbaric processing, vacuum cooling, hypobaric storage).

Unit II: Processing technologies for plant foods

Processing technology for preservation and production of variety food products during storage, handling and processing of cereals/millets and legumes, oilseeds, fruits and vegetables; Food preservation by Hurdle technology and canning technology.

Unit III: Processing technologies for animal foods

Processing technology for milk and milk products, egg, meat, poultry and fish, convenience foods and processed foods; Technologies underlying mutual supplementation, enrichment and fortification, fermentation, malting and germination; Food additives commonly used in food industries for colour, flavour and as preservatives; Nanomaterials as food additives.

Unit IV: Quality control in food processing

Quality control in food industry - raw materials and finished products; Waste management and sanitation in food industries; Packaging - self-cooling self-heating packaging, micro packaging, antimicrobial packaging and water-soluble packaging.

VII. Practicals

1. Effect of blanching on enzymatic activity and volume occupation
2. Effect of refrigeration and freezing on quality of fruits and vegetables
3. Dehydration of fruits and vegetables
4. Canning of fruits and vegetables

5-6. Preparation of fruit candy, squash, nectar, malt beverages and quality evaluation with respect to FPO

7. Clarification of juice using various methods (chemical, enzyme and fining agents)

8-9. Malting of green gram, moth bean- enzymatic activity determination

10. Preparation of Paneer and curd and its quality evaluation
11. Quality evaluation of egg and fish
12. Effect of chemical preservation on storage quality of food (bread, cake).
13. Storage of nuts and oil seeds under vacuum packaging
14. Packaging of fruits and vegetables for transportation distance market using corrugated fibre boxes
15. Transportation of fresh fruits and vegetables using cushioning system and fibre board
16. Visit to food processing unit

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)

- Group activities
- Hands on training

IX. Learning Outcome

This course will help students to

- Utilize the scientific knowledge to become food processing entrepreneur
- Utilize the acquired knowledge for being an expert in any Processing Unit
- Assist in ascertaining quality control of a consumed food in any given situation

X. Suggested Reading

- Brennan JG. 2006. Food Processing Handbook. Wiley-VCH
- Clark S, Jung S and Lamsal B. 2014. Food Processing - Principles and Applications. 2nd Edition, Wiley-Blackwell Publishing Company, Boston.
- Fellows PJ. 2000. Food Processing Technology. Woodhead Publishing Ltd.
- Fellows PJ. 2017. Food Processing Technology, Principles and Practice. 4th Edition, Woodhead Publishing Ltd. Cambridge.
- Hartel R W and Heldman D. 2012. Principles of Food Processing. Aspen Publishers Inc. New York.
- Owens G. 2001. Cereals Processing Technology. Woodhead Publishing Ltd.
- Sivshankar B. 2002. Food Processing and Preservation. Prentice-Hall of India Pvt. Ltd. Delhi.
- Subbalakshmi. 2001. Food Processing and Preservation. New Age International Publishers, New Delhi.
- Vaclavik V. 2018. Dimensions of Food. CRC Press.
- https://www.ift.org
- https://www.foodsciencematters
- https://www.ifst.org

Weekly Lecture Schedule

Duration (week)	Topic
1.	Principle underlying food processing operations including thermal, radiation, refrigeration, freezing and dehydration.
2.	Effect of processing on physiochemical characteristics.
3.	Principles underlying pressure modified processing (high hydrostatic pressure, hyperbaric processing, vacuum cooling, hypobaric storage).
4.	Processing technology for preservation and production of variety food products during storage, handling and processing of cereals, legumes and oilseeds.
5.	Processing technology for preservation and production of fruits and vegetables.
6.	Food preservation by Hurdle technology.
7.	Food preservation by canning technology.
8.	Processing technology for milk and milk products, egg, meat, poultry and fish.
9.	Processing technology for convenience foods and processed foods.
10.	Technologies underlying in mutual supplementation, enrichment and fortification.
11.	Technologies underlying fermentation, malting and germination.
12.	Food additives commonly used in food industries for colour, flavour and as preservatives.

13. Nanomaterials as food additives.
14. Quality control in food industry - raw materials and finished products.
15. Waste management and sanitation in food industries.
16. Packaging - self-cooling self-heating packaging, micro packaging, antimicrobial packaging and water-soluble packaging.

I. Course Title : Human Physiology

II. Course Code : FN 513

III. Credit Hours : 3 (3+0)

IV. Rationale

Physiology is the scientific study of the function and mechanism which work within a living system. Human Physiology seeks to understand the mechanisms that work to keep the human body alive and functioning through scientific enquiry to keep humans healthy and productive. Changes in Physiology in human can impact vital body functions.

V. Aim of the course

- To give theoretical concepts to compleX physiological systems of the human body through scientific enquiry into the nature of mechanical, physical and biochemical function of humans, their organs and cells of which they are composed
- To approach the subject area from variegated angles to equip the students with the knowledge of importance of normal and altered picture of biological markers and suggest remedies.

VI. Theory

Unit I: Circulatory system

Overview of anatomy and functions of human body; Reticuloendothelial system- functions, classification; Lymphatic system- functions, circulation; Circulatory system- blood and composition blood cells, development and function of blood cells, blood clotting, blood grouping and haemoglobin, Heart - anatomy, cardiac cycle, blood pressure and factors affecting blood pressure.

Unit II: Respiratory system

Respiratory system- anatomy, physiology and mechanism of respiration, regulation of respiration; Digestive system- anatomy of gastrointestinal tract and accessory organs, digestion and absorption of food, regulation of appetite.

Unit III: Excretory system

Excretory system- anatomy and functions of kidney, formation, composition and excretion of urine; Endocrine glands, mode of action of hormones.

Unit IV: Reproductive system

Reproductive system- structure and functions of male and female reproductive organs; Anatomy and functions of nervous and musculoskeletal system.

VII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)

- Students' presentation
- Group activities

VIII. Learning Outcome

This course will help students to:

- Apply knowledge in understanding interrelationship between physiology and nutrition.
- Enable to act as a reliable team member in Healthcare team in medical and non- medical setups.
- Apply the acquired techniques for population education

IX. Suggested Reading

- Chaterjee CC. 2012. Human Physiology Vol. I and Vol. II. CBS Publications.
- David F, Stacia BM and Charles LS. 1993. Human Physiology- Foundations and Frontiers. 2nd Edn., Mosby Pub.
- Donnersberger AB and Scott AL. 2005. Laboratory Textbook of Anatomy and Physiology. 8th Edition, Jones and Bartlett Learning, Burlington, Massachusetts.
- Jain AK. 2009. Human Physiology for BD. 3rd Edition, Avichal Publishing Company, New Delhi.
- Hall JE. 2016. Gayton and Hall Text Book of Medical Physiology. 13th Edition, Elsevier India.
- Marieb EN. 2004. Human Anatomy and Physiology 6th Edition. Pearson Education, Inc. London.
- Waugh A and Grant A. 2014. Ross and Wilson Anatomy and Physiology in Health and Illness. 6th Edition, Elsevier Ltd. Churchill Livinstone, London.http://novella.mhhe.com/sites/0073525707/information_center_view0/custom_publishing_
- primis.html
- https://jsums.instructure.com/courses/2144344/pages/welcome-to-holes-human-anatomy- and-physiology-11-slash-e

Weekly Lecture Schedule

Duration (week)	Topic
1	Overview of anatomy and functions of human body.
2	Reticuloendothelial system- functions, classification.
3	Lymphatic system- functions, circulation.
4	Circulatory System- blood and composition blood cells, development and function of blood cells.
5	Blood clotting, blood grouping and haemoglobin.
6	Heart – anatomy and cardiac cycle.
7	Blood pressure and factors affecting it.
8	Respiratory system- anatomy and physiology.
9	Mechanism of respiration and its regulation.
10	Digestive system- anatomy of gastrointestinal tract and accessory organs.
11	Digestion and absorption of food, regulation of appetite.
12	Excretory system- anatomy and functions of kidney.
13	Formation, composition and excretion of urine.
14	Endocrine glands, mode of action of hormones.
15	Reproductive system- structure and functions of male and female reproductive organs.
16	Anatomy and functions of nervous and musculoskeletal system.

I. Course Title : Institutional Food Service Management

II. Course Code : FN 514

III. Credit Hours : 2 (1+1)

IV. Rationale

Institutional food Service Management denotes the entities that provides meals at educational institutes, hospitals, care homes, hotels, public and private cafeteria, etc. Students equipped with updated knowledge in this area will help them to act as an expert to suggest quality food to the customer as per their needs.

V. Aim of the course

- To equip the students with the multi-dimensional knowledge associated with institutional food service in a given setup
- To enable them in planning, execution and control of the management of institutes with ease and profit.

VI. Theory

Unit I: Food service management

Types of food services - organization and management. Tools of management; FSSAI and CODEX guidelines.

Unit II: Record keeping

Personnel management; Books, records and record keeping; Cost control in food services; Menu planning; HACCP.

Unit III: Quantity food production

Meal services management; Types of services; Quantity food production; Principles involved in development of recipes in large scale cooking; Standardization of recipes; Utilization of left-over foods.

Unit IV: Planning of food service unit

Types of kitchens; Planning of layout and equipment for food services; Sanitation and hygiene in handling foods; Personnel hygiene and its importance; Organisation of spaces.

VII. Practicals

1-2. Standardization of basic recipes: planning and preparation

3. Modification in basic recipes

4. Use of left-over foods

5-6. Visit to different types of food service institutions and study the organization, physical plan and layout, food service equipment, sanitation and hygiene.

7-10. Practical experience in organization and management of a college cafeteria/ hotels

11-12. Setting of canteens with formal and informal table setting

13. Scale production of standardised recipes

14-15. Menu planning for snack bars, canteens, residential hostels and hospitals

16. Cost analysis

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- Hands on training

IX. Learning Outcome

This course will help students to:

- Act as front office managers
- Skilled in centralized/ decentralized service providers in medical/ care homes
- Skilled chef and service providers

X. Suggested Reading

- Arora RS. 2012. Banquet and Catering Management. Abhijeet Publications.
- Beckley JH, Herzog LJ and Foley MM. 2017. Accelerating New Food Product Design and Development. 2nd Edition, John Wiley and Sons Inc. Hoboken, New Jersey.
- Carpenter RP, Lyon DH and Hasdell TA. 2002. Guidelines for Sensory Analysis in Food Product Development and Quality Control. 2nd Edition, Aspen Publishers Inc. New York.
- Earle M and Earle RL. 2008. Case Studies in Food Product Development. Woodhead Publishing Limited and CRC Press, New York.
- Harish Bhat. 2008. Hotel Management. Crescent Publishing Corporation.
- Moskowitz HR, Straus T and Saguy S. 2009. An Integrated Approach to New Food Product Development. CRC Press, Boca Raton, Florida.
- Mudit Bhajwani. 2007. Food Service Management: Principles and Practice. Rajat publications, New Delhi.
- Nancy LS. 2007. Catering Management. John Wiley & Sons.
- Puckett RP. 2012. Food Service Manual for Health Care Institutions. 4th Edition, John Wiley and Sons Inc. Hoboken, New Jersey.
- Sethi M. 2018. Catering Management- An Integral Approach. 3rd Edition, New Age International, New Delhi.
- https://www.ferrerofoodservice.com
- https://www.foodservicedirector.com
- Vaclavik V (2018) Dimensions of Food. CRC Press.

M.Sc. (Forestry)

Forest Products and Utilization

Course Title with Credit Load
M.Sc. (Forestry) in Forest Products and Utilization

Course Code	Course Title	Credit Hours
	Major Courses	
FPU 501	Non Wood Forest Products Management	3(2+1)
FPU 502	Applied Wood Technology	3(2+1)
FPU 503	Pulp and Paper Technology	3(2+1)
FPU 504	Composite Wood Technology	3(2+1)
FPU 505	Forest Products Laboratory Techniques	2(0+2)
FPU 506	Agro-techniques of Medicinal and Aromatic Crops	3(2+1)
FPU 507	Breeding Techniques and Improvement of Medicinal	3(2+1)
	and Aromatic Crops	
FPU 508	Chemistry and Processing of Medicinal and Aromatic Plants	3(2+1)
FPU 509	Wood Identification	2(0+2)
FPU 510	Chemistry of Forest Products and Industries	3(2+1)
FPU 511	Wood Chemistry	2(1+1)
FPU 512	Wood Physics	2(1+1)
FPU 513	Wood Seasoning and Preservation	3(2+1)
FPU 514	Production of Medicinal and Aromatic Crops	2(1+1)
FPU 515	Medicinal and Aromatic Plants in Health Care Systems	2(2 +0)
FPU 516	Pharmacognosy of Medicinal and Aromatic Plants	2(1+1)

Course Contents

M.Sc. (Forestry) in Forest Products and Utilization

I. Course Title : Non Wood Forest Products Management

II. Course Code : FPU 501

III. Credit Hours : 3(2+1)

IV. Aim of the course

To make students to understand and learn about the different non wood Forest Products and their scientific extraction, processing and disposal.

V. Theory

UNIT I

Classification of non wood forest products like gums and resins, katha, dyes, tannins, oils, raw drugs, bamboos, canes and other products.

UNIT II

Technologies for extraction of gums, resins, katha, dyes, tannins, oils, raw drugs and other products.

UNIT III

Utilization of various non wood forest products and their scientific management for processing, value addition, marketing and disposal.

UNIT IV

Quality assessment of important products and their methods for storage. Important industries based on non wood forest products and their management.

VI. Practical

- Extraction of resins, gums, katha, dyes, tannins, oils raw drugs, bamboos, canes and other products;
- Value addition techniques for these products;
- Visit to non wood forest products based industries.

VII. Suggested Reading

- Linskens HF and Jackson JF. 1991. Essential Oils and Waxes (Ed.). Springer-Verlag Berlin Heidelberg.
- Mathe A. 2015. Medicinal and Aromatic Plants of the World-Scientific, Production, Commercial and Utilization Aspects. Springer Netherlands.
- Panda H. 2005. Hand Book on Specialty Gums, Adhesive, Oils, Rosin And Derivatives, Resins, Oleoresins, Katha, Chemicals with others Natural Products. Asia Pacific business press. Inc.
- Panshin AJ, Harrer ES and Bethel JS. Forest Products, their Sources, Production and Utilization.
- Shackleton S, Shackleton C and Shanley P. 2011. Non-Timber Forest Products in the Global Context (Ed.). Springer, Verlag Berlin Heidelberg.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Classification of non wood forest products like; gums and resins, katha, dyes, tannins, oils, raw drugs and other products	9
2.	Technologies for extraction of gums, resins, katha, dyes, tannins, oils, raw drugs and other products	8
3.	Utilization of various non wood forest products and their scientific management for processing, value addition and disposal	6
4.	Quality assessment of important products and their methods for storage	6
5.	Important industries based on non wood forest products and their management	3
	Total	**32**
	Practical	
1.	Extraction of resins, gums, katha, dyes, tannins, oils, raw drugs and other products	8
2.	Value addition techniques resins, gums, katha, dyes, tannins, oils, raw drugs and other products	5
3.	Visit to non wood forest products based industries	3
	Total	**16**

I. Course Title : Applied Wood Technology
II. Course Code : FPU 502
III. Credit Hours : 3(2+1)
IV. Aim of the course

To acquaint students with various aspects of wood technology and their role in different applications.

V. Theory

UNIT I

Physical properties of wood-wood density, specific gravity and methods of their determination. Effect of growth on density of wood. Moisture content and its measurement. Effect of sound on wood resonance. Color of wood, phosphorescence, fluorescence and residual luminescence. Thermal properties-conductivity and diffusivity. Electrical properties-conductivity, dielectric constant and current resistivity. Wood permeability.

UNIT II

Mechanical properties-elastic constants, plasticity, Hook's Law, Poisson's ratio, elastic constants, modulus of elasticity, factors affecting strength properties, elastic theory of bending, shear stresses in simple beams, supported beams and cantilevers carrying concentrated and uniformly distributed loads, direct and bending safe working stresses and their evaluation.

UNIT III

Standard tests of timber specimen's-compression, tensile strength. Mechanics and Rheology of wood, abrasion, brittleness and hardness. Suitability coefficient and indices of different wood species. Vibration properties.

UNIT IV

Effect of environment on mechanical properties of wood. Effect of radiations on strength of wood.

VI. Practical

- Determination of density, specific gravity, strength, hardness, modulus of elasticity, mechanical properties, thermal conductivity, electrical resistivity and dielectric constant of important domestic and imported timber species.

VII. Suggested Reading

- Bodig J and Benjamin AJ. 1993. Mechanics of Woods and Woods Composites. Krieger Publish Company.
- Brown HP. 1925. An Elementary Manual on Indian Wood technology. Central Publication Branch, Government of India, Calcutta.
- Brown HP. 1985. Manual of Indian Wood Technology. International Books and Periodicals Supply Service, New Delhi.
- Hill CAS. 2006. Wood Modification: Chemical, Thermal and other Processes. John Wiley and Sons Ltd.
- Hoadley B. 2000. Understanding Wood: A Craftsman's Guide to Wood Technology. Taunton Press. Newtown, USA.
- Kollmann FFP and Cote WAJ. 1968. Principle of Wood Science and Technology. Vol I, Solid
- Wood George Allen and Unwin Ltd London, Springer-Verlag, Berlin, Heidelberg, New York.
- Panshin AJ and De ZC. 1980. Textbook of Wood Technology, 4th Ed. McGraw-Hill. New York.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Physical properties of wood-wood density, specific gravity and methods of determination	4
2.	Effect of growth on density of wood. Moisture content and its measurement. Effect of sound on wood resonance. Phosphorescence, fluorescence and residual luminescence	4
3.	Thermal properties-conductivity and diffusivity	2
4.	Electrical properties-conductivity, dielectric constant and current resistivity. Wood permeability	3
5.	Mechanical properties-elastic constants, plasticity, Hook's Law, Poisson's ratio, elastic constants, modulus of elasticity, factors affecting strength properties, elastic theory of bending, shear stresses in simple beams, supported beams and cantilevers carrying concentrated and uniformly distributed leads, direct and bending safe working stresses in simple and their evaluation	8
6.	Standard tests of timber specimen's-compression, tensile strength, Mechanics and Rheology of wood, abrasion, brittleness and hardness.	5
7.	Suitability coefficient and indices of different wood species.Vibration properties	3
8.	Effect of environment on mechanical properties of wood. Effect of radiations on strength of wood	
	Total	**32**

	Practical	
1.	Determination of density, strength, hardness modulus of elasticity of wood and mechanical properties of important domestic and imported timber species	9
2.	Determination electrical resistivity and dielectric constant of important domestic and imported timber species	7
	Total	**16**

I. Course Title : Pulp and Paper Technology
II. Course Code : FPU 503
III. Credit Hours : 3(2+1)
IV. Aim of the course

To acquaint the students with the resources and processes for making pulp and paper.

V. Theory

UNIT I

Raw material used in pulp and paper industries, characteristics and handling.

UNIT II

Pulping process, mechanical, chemical, semi-chemical and biopulping. Pulp bleaching, pulp treatment, defibering, de-knotting, brown stock washing, screening, cleaning, thickening, etc.

UNIT III

Recycled fibers, supplementary pulp treatment and additives. Paper making, paper drying, reeling, external sizing, coating, calendaring, etc.

UNIT IV

Structure of paper, its characterization and measuring strength method, optional and structural properties of paper, Type of paper: coated paper, corrugated containers, printing quality of paper, ageing of paper. Rayon industry.

VI. Practical

- Visit to pulp and paper industry;
- Study of raw materials, techniques and pulp yield, making of paper and its quality determination.

VII. Suggested Reading

- Asuncion J. 2003. The Complete Book of Paper Making. Lark books, New York.
- Bajpai P. 2018. Biermann's Handbook of Pulp and Paper. Vol. 1st:Raw material and pulp making. Elsevier Science, UK.
- Biermann C. 1996. Handbook of Pulping and Paper Making. 2nd Ed. Academic Press San Diego, New York, Boston, London, Sydney, Tokyo, Toronito.
- Britt KW. 1970. Handbook of Pulp and Paper Technology. 2nd Ed. Van Nostrand Reinhold Company, New York.

- Lavigne JR. 1979. Instrumentation Applications for the Pulp and Paper Industry. Miller Freeman Publications.
- Rao KP. 2007. Pulp and Paper Technology: Technology, Testing and Applications. CBS Publishing and Distributors, New Delhi.
- Sjostrom E and Alen R (Eds). 1999. Analytical Methods in Wood Chemistry Pulping and Paper Making. Springer Series in Wood Science.
- Viikari L and Lantto R. 2002. Progress in Biotechnology. Vol. 21st. Biotechnology in the pulp and paper industry. 1st Ed. ICBPPI. Elsevier Science.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Raw materials used in pulp and paper industries, characteristics and handling	6
2.	Pulping process, mechanical, chemical, semi-chemical and biopulping. Pulp bleaching, pulp treatment, defibering, de-knotting, brown stock washing, screening, cleaning, thickening, etc.	8
3.	Recycled fibers, supplementary pulp treatment and additives. Paper making, paper drying, reeling, external sizing, coating, calendaring, etc. Structure of paper, its characterization and measuring strength method	10
4.	Optional and structural properties of paper, Type of paper: coated paper, corrugated containers, printing quality of paper, ageing of paper	6
5.	Rayon industry	2
	Total	**32**
	Practical	
1.	Visit to pulp and paper industry	6
2.	Study of raw materials, techniques and pulp yield, making of paper and its quality determination	10
	Total	**16**

I. Course Title : Composite Wood Technology
II. Course Code : FPU 504
III. Credit Hours : 3(2+1)
IV. Aim of the course

To impart knowledge regarding the scope and processes for developing composite and modified woods.

V. Theory

UNIT I

Introduction to wood modification, its need and scope.Chemical modification of wood (acetylation, reaction with isocyanates, acetates, ethers, epoxides, etc.) Wood impregnation and compregnation, heat stabilization, wood densification.

UNIT II

Modern trends in composite wood. Wood adhesives – types, characteristics and application.

UNIT III

Plywood, laminated wood and inorganic wood composites- their manufacture, characteristics and application.

VI. Practical

- Use of different adhesives in plywood;
- Study of composite boards, study of anti-shrink efficiency of wood treated with different chemicals;
- Impregnation and compregnation of wood with chemicals.

VII. Suggested Reading

- Ansell MP. 2015.Wood Composites. Elsevier, Science and Technology.
- Hill CAS. 2006. Wood Modification: Chemical, Thermal and Other Processes. John Wiley and Sons Ltd.
- Pizzi A and Mittal KL. 2011. Wood Adhesives. CRC Press, New York.
- Rowell RM. 2013. Handbook of Wood Chemistry and Wood Composites. 2nd Ed. CRC Press, New York.
- USDA (U.S. Department of Agriculture). 1999. Wood Handbook: Wood as an Engineered Material. US Department of Agriculture, Forest Service. Forest Products Laboratory, Madison, WI.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction to wood modification, its need and scope	4
2.	Chemical modification of wood (acetylation, reaction with isocyanates, acetates, ethers, epoxides, etc.)	6
3.	Wood impregnation and compregnation, heat stabilization, wood densification	6
4.	Modern trends in composite wood	4
5.	Wood adhesives - types, characteristics and application	4
6.	Plywood, laminated wood and inorganic wood composites- their manufacture, characteristics and application	8
	Total	**32**
	Practical	
1.	Use of different adhesives in plywood	4
2.	Study of composite boards, study of anti-shrink efficiency of wood treated with different chemicals	6
3.	Impregnation and compregnation of wood with chemicals	6
	Total	**16**

I. Course Title : Forest Products Laboratory Techniques

II. Course Code : FPU 505

III. Credit Hours : 2(0+2)

IV. Aim of the course

To expose the students to the practical aspects of laboratory techniques employed in forest products.

V. Practical

- Wood and non-wood product sampling, drying and storage. Estimation of extraneous components of wood. Analysis of volatile compounds;
- Estimation of chemical composition of wood samples (hardwoods, softwood and other lignocellulosic material) and ash;
- Separation of components by column, paper, and thin layer chromatography. HPLC techniques;
- Determination of strength properties of paper and wood composites.

VI. Suggested Reading

- Meyland BA and Butterfield BG. 1972. Three-Dimensional Structure of Wood: A Scanning Electron Microscope Study. Syracuse University Press.
- Rowell RM. 2013. Handbook of Wood Chemistry and Wood Composites. 2nd Ed. CRC Press, New York.
- Skaar C. 1988. Wood-Water Relations. Springer Series in Wood Science.
- Snyder LR, Kirkland JJ and Glajch JL. 2012. Practical HPLC Method Development. 2nd Ed. John Wiley & Sons.

Lecture Schedule

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Wood and non-wood products sampling, drying and storage	4
2.	Estimation of extraneous components of wood. Analysis of volatile compounds	6
3.	Estimation of chemical composition of wood samples (hardwoods, softwood and other lignocellulosic material) and ash	10
4.	Separation of components by column, paper and thin layer chromatography. HPLC techniques	6
5.	Determination of strength properties of paper and wood composites	6
	Total	**32**

I. Course Title : Agro-techniques of Medicinal and Aromatic Crops
II. Course Code : FPU 506
III. Credit Hours : 3(2+1)
IV. Aim of the course

To equip the student with the conventional and commercial production techniques of medicinal and aromatic plant species.

V. Theory

UNIT I

Importance of medicinal and aromatic plants in human health, national economy and related industries. Need of cultivation of medicinal and aromatic plants as agricultural crops. Concept of organic farming, GACP and GAP in medicinal and aromatic crops production. Quality concern in plant based drugs.

UNIT II

Introduction and importance, climate and soil requirements, cultural practices, harvesting and yield, important constituents of medicinal plants – Mulhathi, Senna, Gloriosa superba, Valeriana jatamansi, Swertia chirayita, Isabgol, Rauwolfia serpentina, Withania sominifera, Opium Poppy, Aloe vera, Satavar, Stevia rebaudiana, Safed Musli, Kalmegh and other important species of the region.

UNIT III

Introduction and importance, climate and soil requirements; cultural practices; harvest and yield; important constituents of aromatic plants – Citronella, Palmarosa, Mentha, Basil, Lemon grass, Rose, Tagetes minuta, Lavender, Rosemary, Patchouli, Geranium and other important species of the region.

VI. Practical

- Morphological identification of listed plants and their economic parts, maturity indices;
- Preparation and layout of nursery and field, methods of seed sowing/ transplantation, cultural operations in MAP crops;
- Raising and harvesting of at least one crop grown in the region;
- Visit to government and private Pharmaceutical units/ Institutes in adjoining areas;
- Visit to large scale herb growing and processing units engaged in commercial cultivation and preparation of purified phytochemical/ standardized eXtracts;
- Visit to nearby marketing/ trade centres.

VII. Suggested Reading

- Atul CK and Kapur BK. 1982. Cultivation and Utilization Of Medicinal Plants. RRL, CSIR, Jammu-Tawi.
- Chadha KL and Gupta R. 2006. Advances in Horticulture. Vol. XI. Medicinal and aromatic plants. Malhotra Publishing House.
- Chopra AK. 2007. Medicinal Plants: Conservation, Cultivation and Utilization. Daya Books.
- Chopra RN. Nayar SL and Chopra IC. 1956. Glossary of Indian Medicinal Plants. CSIR, New Delhi.

- EIRI Board. 2007. Handbook of Medicinal and Aromatic Plants: Cultivation, Utilization and Extraction Processes. Engineers India Research Institute, New Delhi.
- Gunther E. 1975. The Essential Oils. Robert, K Krieger Pub. Co, New York.
- Khan IA and Khanum A. 2005. Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health. 1st Ed. Ukaaz Publications.
- Muralia S. 2006. Medicinal and Aromatic Plants 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Importance of medicinal and aromatic plants in human health, national economy and related industries. Need of cultivation of Medicinal and aromatic plants as agricultural crops	2
2.	Concept of organic farming, GACP and GAP in medicinal and aromatic crop production. Quality concern in plant based drugs	3
3.	Introduction and importance, botanical features, climate and soil requirements, cultural practices, harvesting and yield and important constituents of medicinal plants – Mulhathi, Senna, Gloriosa superba, Valeriana jatamansi, Swertia chirayita, Isabgol, Rauwolfia serpentina, Withania somnifera, Opium Poppy, Aloe vera, Satavar, Stevia rebaudiana, Safed Musli, Kalmegh and other important species of the region	15
4.	Introduction and importance, climate and soil requirements; cultural practices; harvest and yield; important constituents of aromatic plants - Citronella, Palmarosa, Mentha, Basil, Lemon grass, Rose, Tagetes minuta, Lavender, Rosemary, Patchouli, Geranium and other important species of the region	12
	Total	**32**
	Practical	
1.	Morphological identification of listed plants and their economic parts, maturity indices	3
2.	Preparation and layout of nursery and field, methods of seed sowing/ transplantation, cultural operations in MAP crops	4
3.	Raising and harvesting of at least one crop grown in the region	3
4.	Visit to government and private Pharmaceutical units/ Institutes in adjoining areas. Visit to large scale herb growing and processing units engaged in commercial cultivation and preparation of purified phytochemical/ standardized extracts	4
5.	Visit to nearby marketing/ trade centres	2
	Total	**16**

I. Course Title : Breeding Techniques and Improvement of Medicinal and Aromatic crops

II. Course Code : FPU 507

III. Credit Hours : 3(2+1)

IV. Aim of the course

To acquaint with the breeding techniques and quality improvement of medicinal and aromatic crops.

V. Theory

UNIT I

Plant biodiversity, Major objectives of breeding of medicinal and aromatic crops. Plant introduction, domestication and germplasm conservation. Modes of pollination, male sterility, self incompatibility and apomiXis. Production and maintenance of pure seeds of medicinal and aromatic plants.

UNIT II

Principles of plant breeding for self pollinated and cross pollinated crops. Selection, Hybridization-techniques and consequences. Hetersosis and inbreeding depression. Different plant breeding methods for self pollinated, cross pollinated and asexually propagated crops. Mutation and polyploidy breeding. Distinctiveness, uniformity, stability testing in medicinal and aromatic crops.

UNIT III

Breeding for quality parameters in medicinal and aromatic crops. Achievements and prospects in breeding of important medicinal and aromatic crops- Rauvolfia serpentina, Plantago ovata, Cassia angustifolia, Ocimum spp., Withania somnifera, Valeriana spp., Opium poppy, Gloriosa superb, Andrographis paniculata, Mentha spp., Geranium, Cymbopogon spp., and other important crops.

UNIT IV

Legislation in conservation of medicinal and aromatic plants- IPR issues in medicinal and aromatic plants.

VI. Practical

- Identification based on morphological features;
- Pollen viability and germination testing;
- Stigma receptivity;
- Field practice in emasculation, selfing and crossing in different medicinal and aromatic crops;
- Determination of mode of pollination and hybridization in different medicinal and aromatic crops.

VII. Suggested Reading

- Alikhan I and Khanum A. 2008. Role of Biotechnology in Medicinal and Aromatic Plants. UKAZ Publishers.
- Chadha KL and Gupta R. 2006. Advances in Horticulture. Vol. XI. Medicinal and aromatic plants. Malhotra Publishing House.
- Gupta AK and Sharma M. 2008. Reviews on Indian Medicinal Plants. ICMR.
- Gupta AK, Tandon N and Sharma M. 2008. Quality Standards of Indian Medicinal Plants. ICMR.

- Johnson CB and Franz C. 2005. Breeding Research on Aromatic and Medicinal Plants.
- International Book Distributor.
- Sharma R. 2004. Agrotechniques of Medicinal Plants. Daya Publishing.
- Singh BD. 2010. Plant Breeding- Principles and Methods. Kalyani Publishers.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Plant biodiversity, Major objectives of breeding of medicinal and aromatic crops. Plant introduction, domestication and germplasm conservation	3
2.	Modes of pollination, male sterility, self incompatibility and apomixis. Production and maintenance of pure seeds of medicinal and aromatic plants	3
3.	Principles of plant breeding for self pollinated and cross pollinated crops	3
4.	Selection, Hybridization-techniques and consequences	2
5.	Hetersosis and inbreeding depression	3
6.	Different plant breeding methods for self pollinated, cross pollinated and aseXually propagated crops	5
7.	Mutation and polyploidy breeding	2
8.	Distinctiveness, uniformity, stability testing in medicinal and aromatic crops	3
9.	Breeding for quality parameters in medicinal and aromatic crops	2
10.	Achievements and prospects in breeding of important medicinal and aromatic crops- Rauvolfia serpentina, Plantago ovata, Cassia angustifolia, Ocimum sp., Withania somnifera, Valeriana sp., Opium poppy, Gloriosa superba, Andrographis paniculata, Mentha sp., Geranium, Cymbopogon sp., and other important crops	5
11.	Legislation in conservation of medicinal and aromatic plants- IPR issues in medicinal and aromatic plants	1
	Total	**32**
	Practical	
1.	Identification based on morphological features	3
2.	Pollen viability and germination testing	3
3.	Stigma receptivity	2
4.	Field practice in emasculation	2
5.	Selfing and crossing in different medicinal and aromatic crops	4
6.	Determination of mode of pollination and hybridization in different medicinal and aromatic crops	2
	Total	**16**

I. **Course Title : Chemistry and Processing of Medicinal and Aromatic Plants**

II. **Course Code : FPU 508**

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

IV. Aim of the course

To understand the chemistry of phytopharmaceuticals and their processing as industrial products.

V. Theory

UNIT I

Organic compounds and their classification such as aliphatic, aromatic, alkaloids, steroids, terpenoids, glycosides, phenolic compounds, heterocyclic compounds and carbohydrates.

UNIT II

Primary and Secondary plant metabolites and theurapeutical uses of phytoconstituents such as anthraquinones, steroidal and triterpenoidal glycosides, phenolic compounds, lipids, alkaloids and terpenoids.

UNIT III

Basic principles and extraction techniques of different phytoconstituents. Analysis of active principles using TLC, HPLC, Gas chromatography, etc. Quality standards in herbal products. Drug descriptors for medicinal and aromatic plants.

UNIT IV

Postharvest processing-drying, grading and storage. essential oils and their quality analysis.

VI. Practical

- Use of thin layer and column chromatography during extraction and purification of phytopharmaceuticals;
- Preparation of active constituent enriched extracts;
- Extraction of Essential oils and their quality evaluation;
- Preparation of concretes and absolutes. Use of HPLC and GC in quality evaluation.

VII. Suggested Reading

- Bedi S, Singh T and Vyas SP. 2012. A Handbook of Aromatic and Essential Oil Plants: Cultivation, Chemistry, Processing and Uses. Agrobios (India).
- Finar IL. 2002. Organic Chemistry. Vol. I & II. Pearson Education India.
- Raaman N. 2006. Phytochemical Techniques. New India Publishing Agency, N. Delhi.
- Singh MP and Panda H. 2005. Medicinal Herbs with their Formulations. Vol-1st. Daya Publishing House.
- Singh S. 2009. Essentials of Pharmacology. 2nd Ed. New Age International Publisher.
- Wagner H and Bladt S. 2009. Plant Drug Analysis- A Thin Layer Chromatography Atlas. Springer (India) Pvt. Ltd.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Organic compounds and their classification such as aliphatic, aromatic, alkaloids, steroids, terpenoids, glycosides, phenolic compounds, heterocyclic compounds and Carbohydrates	9
2.	Primary and secondary plant metabolites	4
3.	Theurapeutical uses of phytoconstituents such as anthraquinones, steroidal and triterpenoidal glycosides, phenolic compounds, lipids, alkaloids and terpenoids	6
4.	Basic principles and extraction techniques of different . phytoconstituentsAnalysis of active principles using TLC, HPLC, Gas chromatography, etc. Quality standards in herbal products	4
5.	Drug descriptors for medicinal and aromatic plants	2
6.	Postharvest processing-drying, grading and storage	4
7.	Extraction techniques of essential oils and their quality analysis	3
	Total	**32**
	Practical	
1.	Use of thin layer and column chromatography during extraction and purification of phytopharmaceuticals	3
2.	Preparation of active constituent enriched extracts	3
3.	Extraction of Essential oils and their quality evaluation	2
4.	Preparation of concretes and absolutes	2
5.	Use of HPLC and GC in quality evaluation	6
	Total	**16**

I. Course Title : Wood Identification
II. Course Code : FPU 509
III. Credit Hours : 3(0+2)
IV. Aim of the course

The course deals with the use of anatomical features of wood in timber identification and classification.

V. Practicals

- Study of planes of wood, gross features and physical characteristics of important woods;
- Identification of different types of cells and tissues;
- Anatomical studies of soft and hard woods. Anatomical studies of reaction wood;
- Classification of timber using dichotomous key;
- Modern timber identification techniques.

VI. Suggested Reading

- Agarwal VK and Upadhaya SD. 2006. Agrotechniques of Medicinal and Aromatic Plants. Satish Serial Publishing House.
- Anoop EV. 1971. Timber Identification Manual. Forest Research Institute, Dehradun.
- Dutta JC. 1964. Botany for Degree Students. Oxford University Press, Bombay-Calcutta-Madras.
- Govil JN, Pandey J, Shivakumar BG and Singh VK. 2004. Crop Improvement, Production Technology, Trade Commerce.
- Lakshman HC and Inchal RF. 2012. Indigenous Medicinal Plants and their Practical Utility. Meier E. 2015. Wood Identifying and Using Hundreds of Woods Worldwide. Wood database. Porter T. 2004. Wood Identification and Use. Guild of Master Craftsman, UK.
- Purkayastha SK. 1982. Indian Woods: Their Identification Properties and Uses. Controller of Publication.
- Rao R and Juneja KDS. 1971. A Handbook for Field Identification of Fifty Important Timbers of India. Manager of Publications.
- Vashishta PC. 1985. A Text Book of Botany. S. Chand Publishing Company, New Delhi.

Lecture Schedule

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Study of planes of wood,gross features and physical characteristics of important woods	6
2.	Identification of different types of cells and tissues	5
3.	Anatomical studies of soft and hard woods. Anatomical studies of reaction wood	10
4.	Classification of timber using dichotomous keys	6
5.	Modern timber identification techniques	5
	Total	**32**

I. Course Title : Chemistry of Forest Products and Industries
II. Course Code : FPU 510
III. Credit Hours : 3(2+1)
IV. Aim of the course

The course will equip the students regarding forest based industries and their impact on the economy of the country. To support the studies on the role of various products such as pulp, paper, composite wood, furniture match boxes, sports, pencil making, resins and gums, katha, tannins and various types of other non- timber and wood products either produced or processed in these industries. Practicals will make them aware regarding extraction and processing methods of different forest products.

V. Theory

UNIT I

Importance of forest based industries in relation to Indian economy. Role of Chemistry in relation to forest products.

UNIT II

Classification and description of different forest based industries – pulp and paper, composite wood, furniture, bamboo, sports goods, pencil making, match box and splint making. Use of lesser known wood species for commercial purposes.

UNIT III

Cell wall constituents. Chemistry of cellulose, starch, hemicelluloses and lignin. Extraneous components of wood – water and organic solvent soluble.

UNIT IV

Chemical composition of oleoresin from major pine species. Structural difference among different gums (arabic, ghatti, tragacanth, etc.).

UNIT V

Chemical nature and uses of volatile oils, tannins, katha and cutch and important forest based dyes and pigments.

VI. Practical

- Estimation of cell wall constituents – Hemicelluloses and lignin;
- Extraction of essential oils, resins and tannins;
- Wood pulping. Acetylation of wood;
- Visit to nearby forest based industries.

VII. Suggested Reading

- Bowyer JL, Shmulsky R and Haygreen JG. 2003. Forest Products and Wood Science: An Introduction. 4th Ed. Blackwell Publishing.
- Chung and Deborah DL. 2003. Composite Materials-Functional Materials for Modern Technologies. Springer,Verlag London.
- David AT. 2013. Forest Products: Advanced Technologies and Economic Analyses.
- Elsevier. Eriksson KEL, Blanchette RA and Ander P. 1990. Microbial and Enzymatic Degradation of Wood and Wood Components. Springer,Verlag Berlin Heidelberg.
- Linskens HF and Jackson JF. 1991. Essential Oils and Waxes (Ed.). Springer-Verlag Berlin Heidelberg.
- Panda H. 2005. Hand Book on Specialty Gums, Adhesive, Oils, Rosin And Derivatives, Resins, Oleoresins, Katha, Chemicals with Others Natural Products. Asia Pacific business press. Inc.
- Rojas OJ. 2016. Cellulose Chemistry and Properties: Fibers, Nanocelluloses and Advanced Materials (Ed.). Springer International Publishing.
- Rowell RM. 2013. Hand Book of Wood Chemistry and Wood Composites. CRC press, Taylor and Francis group.
- Shackleton S, Shackleton C and Shanley P. 2011. Non-Timber Forest Products in the Global Context (Ed.). Springer, Verlag Berlin Heidelberg.
- Sharma LC. 2012. Development of Forests and Forest Based Industries. M/s Bishen Singh Mahendra Pal Singh.

Lecture Schedule

Sr. No	Topic	No. of Lecture (s)
	Theory	
1.	Importance of forest based industries in relation to Indian economy	1
2.	Role of chemistry in relation to forest products	1
3.	Classification and description of different forest based industries – pulp and paper and composite wood	6
4.	Classification and description of different forest based industries like; Furniture, bamboo, sports goods, pencil making, match box and splint making	5
5.	Use of lesser known wood species for commercial purposes	2
6.	Cell wall constituents. Chemistry of cellulose, starch, hemicelluloses and lignin	4
7.	Extraneous components of wood – water and organic solvent soluble	2
8.	Chemical composition of oleoresin from major pine species	3
9.	Structural difference among different gums (arabic, ghatti, tragacanth, etc.)	2
10.	Chemical nature and uses of volatile oils, tannins, katha and cutch	3
11.	Chemical nature and uses of important forest based dyes and pigments	3
	Total	**32**
	Practical	
1.	Estimation of cell wall contents – Hollocellulose and lignin	5
2.	Extraction of essential oils	2
3.	Extraction of resins and tannins	3
4.	Wood pulping	2
5.	Acetylation of wood	2
6.	Visit to nearby forest based industries	2
	Total	**16**

I. Course Title : Wood Chemistry
II. Course Code : FPU 511
III. Credit Hours : 2(1+1)
IV. Aim of the course

To impart knowledge about the chemical properties of wood, cell wall constituents and wood eXtractions.

V. Theory

UNIT I

Chemical composition of wood: Cell wall constituents- cellulose, lignin, hemicellulose, peptic substances, etc.

UNIT II

Volatile oils and extractives, cellulose derivatives and their applications.

UNIT III

Hydrolysis and fermentation of lignocellulosic materials. Pyrolysis and gasification of wood.

VI. Practical

- EXtraction of cellulose, hemicellulose, lignin, extractives and ash content of wood.

VII. Suggested Reading

- Coppen JJW. 1995. Gums, Resin and Latex of Plant Origin. Food and Agriculture Organizations, Rome.
- Rowe JW. 1989. Natural Products of Woody Plants. Springer Series in Wood Science.
- Rowell RM. 1984. The Chemistry of Solid Wood (Advances in Chemistry Series). American Chemical Society.
- Rowell RM. 2013. Handbook of Wood Chemistry and Wood Composites. 2nd Ed. CRC Press.
- Singh A. 1967. Plant Physiology. Readers in Botany, Allahabad University.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Chemical composition of wood: Cell wall constituents- cellulose, lignin, hemicellulose, peptic substances, etc.	5
2.	Volatile oils and extractives, cellulose derivatives and their applications	4
3.	Hydrolysis and fermentation of lignocellulosic materials	4
4.	Pyrolysis and gasification of wood	3
	Total	**16**
	Practical	
1.	Extraction of cellulose	3
2.	Ectraction of Hemicellulose	3
3.	Ectraction of lignin	4
4.	Ectraction of wood ectractives	3
5.	Ectraction of ash content of wood	3
	Total	**16**

I. Course Title : Wood Physics
II. Course Code : FPU 512
III. Credit Hours : 2(1+1)
IV. Aim of the course

To acquaint with the physical characteristics and strength properties of wood.

V. Theory

UNIT I

Wood density, thermal, electrical and acoustic properties of wood. Mechanics and Rheology of wood, elasticity, plasticity and creep (tensile compression and bending strength)

UNIT II

Toughness, torsion, shear, hardness and abrasion strength. Acoustic and acousto- ultrasonics based non-destructive evaluation technique.

VI. Practical

- Determination of wood density;
- Study of thermal, electrical and acoustic properties of wood;
- Determination of tensile and bending properties of wood.

VII. Suggested Reading

- Brown HP. 1925. An Elementary Manual on Indian Wood Technology. Central Publication Branch Government of India.
- Dutta AC. 1964. Botany for Degree Students. Oxford University Press.
- Franz FP, Kollmann and Wilfred AJC. 1968. Principle of Wood Science and Technology. Vol I. Solid wood. George Allen and Unwin Ltd London, Springer-Verlag, Berlin, Heidelberg.
- Franz FP, Kollmann, Kuwnzi E and Stamm AJ. 1975. Principle of Wood Science and Technology. Wood based material. Vol. II Springer-Verlag, Berlin, Heidelberg.
- Meyland BA and Butterfield BG (Eds). 1972. Three-Dimensional Structure of Wood: A Scanning Electron Microscope Study. Syracuse University Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Wood density, thermal, electrical and acoustic properties of wood.	4
2.	Mechanics and Rheology of wood, elasticity, plasticity and creep (tensile compression and bending strength)	5
3.	Toughness, torsion, shear, hardness and abrasion strength	4
4.	Acoustic and acousto-ultrasonics based non-destructive evaluation technique	3
	Total	**16**
	Practical	
1.	Determination of wood density,	7
2.	Study of thermal, electrical and acoustic properties of wood	5
3.	Determination of tensile and bending properties of wood	4
	Total	**16**

I. Course Title : Wood Seasoning and Preservation

II. Course Code : FPU 513

III. Credit Hours : 3(2+1)

IV. Aim of the course

To understand the importance of wood seasoning and preservation for utilizing secondary timber for multipurpose use.

V. Theory

UNIT I

Wood water relationship, absorption behaviour and wood drying, Refractory and non refractory behaviour of wood, Wood seasoning, types- air, kiln and special seasoning methods like steaming, chemical, high temperature drying, vacuum drying and water conditioning.

UNIT II

Defects of timber- natural, seasoning defects, defects due to machining defects. Effect of defects on utilization.

UNIT III

Detection and diagnosis of discolouration and decay in wood: decaying agencies- fungi, insects, borer, etc.

UNIT IV

Wood preservation: preservatives and treatment processes. Advantages and safety concern of wood preservatives, fire retardants. Graveyard test and anti-fungal activity of wood. Bio-preservation.

VI. Practical

- Determination of moisture content and swelling coefficients of different woods;
- Comparative studies on air and kiln dried woods;
- Analysis of decayed wood for physical and chemical parameters;
- Treatment of wood with different types of preservatives. Graveyard test.

VII. Suggested Reading

- FAO. 2007. Wood Preservation Manual. International Book Distributor. Hunt GM. 1967. Wood Preservation 3rd Ed. Mc GRAW-HILL Book Company.
- Pandey CN and Jain VK. 1992. Wood Seasoning Technology. FRI, Dehradun.
- Purushotham A, Pande JN and Jadhav. 1959. Wood Preservation In India. Manager of Publications.
- Winn W. 1919. Timbers and their Uses. London George Rotledge & Sons Ltd.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Wood water relationship, absorption behaviour and wood drying	4
2.	Refractory and non refractory behaviour of wood	4
3.	Wood seasoning, types- air, kiln and special seasoning methods like steaming, chemical, high temperature drying, vacuum drying and water conditioning	6
4.	Defects of timber- natural, seasoning defects, defects due to eXternal agencies, machining defects	4
5.	Effect of defects on utilization	2
6.	Detection and diagnosis of discolouration and decay in wood: decaying agencies- fungi, insects, borer, etc.	4
7.	Wood preservation: preservatives and treatment processes	2
8.	Advantages and safety concern of wood preservatives, fire retardants	2
9	Graveyard test and anti-fungal activity of wood. Bio-preservation	4
	Total	**32**
	Practical	
1.	Determination of moisture content and swelling coefficients of different woods	3
2.	Comparative studies on air and kiln dried woods	3
3.	Analysis of decayed wood for physical and chemical parameters	4
4.	Treatment of wood with different types of preservatives. Graveyard test	6
	Total	**16**

I. Course Title : Production of Medicinal and Aromatic Crops
II. Course Code : FPU 514
III. Credit Hours : 2(1+1)
IV. Aim of the course

To acquaint the students with the plant production techniques.

V. Theory

UNIT I

Modes of reproduction in MAP crops and their relevance in maintaining genetic purity of crops. Concept of quality seed production and maintenance.

UNIT II

Soil fertility, essential nutrient elements- functions, deficiency symptoms, availability and factors affecting their availability. Soil micro-organisms and their role in organic matter decomposition. Importance of pH and C:N ratio in plant nutrition. Concept of bio-fertlizers and their potential for use in medicinal and aromatic crops.

UNIT III

Essentials of nursery production, criteria of site selection, and types of nursery, establishment of a model nursery. Nursery raising of medicinal plants. Tissue culture technique and in-vitro propagation of important MAPs.

UNIT IV

Plant protection measures in medicinal and aromatic crops, Quality parameters of seedlings and nursery stock.

VI. Practical

- Asexual/ vegetative reproduction techniques- cutting, budding, layering, etc.;
- Methods of seed collection and storage techniques;
- In-vitro propagation techniques;
- Determination of pH, organic matter and N,P,K from soil.

VII. Suggested Reading

- Atul CK and Kapur BK. 1982. Cultivation and Utilization of Medicinal Plants. RRL, CSIR, Jammu-Tawi.
- Chopra AK. 2007. Medicinal Plants: Conservation, Cultivation and Utilization. Daya Books. Chopra RN. Nayar SL and Chopra IC. 1956. Glossary of Indian Medicinal Plants. CSIR, New Delhi.
- EIRI Board. 2007. Handbook of Medicinal and Aromatic Plants: Cultivation, Utilization and Extraction Processes. Engineers India Research Institute, New Delhi.
- Gunther E. 1975. The Essential Oils. Robert, K Krieger Pub. Co, New York.
- Khan IA and Khanum A. 2005. Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health. 1st Ed. Ukaaz Publications.
- Muralia S. 2006. Medicinal and Aromatic Plants 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Modes of reproduction in crop plants and their relevance in maintaining genetic purity of crops. Concept of quality seed production and maintenance	2
2.	Soil fertility, essential nutrient elements- functions, deficiency symptoms, availability and factors affecting their availability. Soil micro-organisms and their role in organic matter decomposition. Importance of pH and C:N ratio in plant nutrition. Concept of bio- fertlizers and their potential for use in medicinal and aromatic crops	5
3.	Essentials of nursery production, criteria of site selection, and types of nursery, establishment of a model nursery. Nursery raising of medicinal plants. Mode of plant propagation techniques. Tissue culture technique and in-vitro propagation of important MAPs	6
4.	Plant protection measures in medicinal and aromatic crops, Quality parameters of seedlings and nursery stock	3
	Total	**16**

Practical

1.	Asexual/ vegetative reproduction techniques-cutting, budding, layering, etc.	5
2.	Methods of seed collection and storage techniques	2
3.	In-vitro-propagation techniques	3
4.	Determination of pH, Organic matter and N,P,K from soil	6
	Total	**16**

I. Course Title : Medicinal and Aromatic Plants in Health Care Systems
II. Course Code : FPU 515
III. Credit Hours : 2(2+0)
IV. Aim of the course

To acquaint the student with the importance of plants used in modern and AYUSH methods of treatment.

V. Theory

UNIT I

Concept of Health Care systems

UNIT II

Brief introduction to Ayurveda, Unani, Sidha, Homeopathy, Allopathy, Naturopathy, Electrohomoeopathy, etc.

UNIT III

Important medicinal plants used in treating various diseases in modern and complementary systems.

UNIT IV

Biological activity of selected medicinal plants. Methods of preparing poultices, decoctions, powders, tinctures, active content rich extracts.

VI. Suggested Reading

- Atul CK and Kapur BK. 1982. Cultivation and Utilization of Medicinal Plants. RRL, CSIR, Jammu-Tawi.
- Chopra AK. 2007. Medicinal Plants: Conservation, Cultivation and Utilization. Daya Books. Chopra RN. Nayar SL and Chopra IC. 1956. Glossary of Indian Medicinal Plants. CSIR, New Delhi.
- Cunningham A. 2014. Applied Ethnobotany: "People, Wild Plant Use and Conservation". Taylor & Francis.
- Gunther E. 1975. The Essential Oils. Robert, K Krieger Pub. Co, New York.
- Jain SK. 1968. Medicinal Plants. National book trust, New Delhi. Oxford & IBH, New Delhi.
- Khan IA and Khanum A. 2005. Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health. 1st Ed. Ukaaz Publications.

- Maheshwari JK. 2000. Ethnobotany and Medicinal Plants of Indian Subcontinent. Scientific Publishers,Jodhpur, India.
- Muralia S. 2006. Medicinal and Aromatic Plants 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Concept of Health Care systems	2
2.	Brief introduction to Ayurveda, Unani, Sidha, Homeopathy, Allopathy, Naturopathy, Electrohomoeopathy, etc.	10
3.	Important medicinal plants used in treating various diseases in modern and complementary systems.	6
4.	Biological activity of selected medicinal plants.	6
5.	Methods of preparing poultices, decoctions, powders, tinctures, active content rich extracts	8
	Total	**32**

I. Course Title : Pharmacognosy of Medicinal and Aromatic Plants
II. Course Code : FPU 516
III. Credit Hours : 2(1+1)
IV. Aim of the course

To develop understanding about microscopical, macroscopical and chemical methods of drug identification.

V. Theory

UNIT I

History and scope of pharmacognosy, Pharmaceutical products. Classification of natural drugs. Chemical nature of drugs. Pharmacognostic analysis of drug plants based on botanical, chemical and histological features.

UNIT II

Evaluation based on pharmacopoeial standards for both single drugs and compound formulations most commonly used in different systems of medicines.

UNIT III

Pharmacognostic features of Sarpagandha, Jatamansi, Ashwagandha, Turmeric, Punarnava, Ephedra, Gymnema, Senna, Amla, Gokhru, Isabgol, Black pepper, Banafsha, Arjun or any other commercially species specific to the region.

VI. Practical

- Identification of drugs by morphological characters;
- Physical and chemical tests for evaluation of drugs;

- Gross anatomical studies of Ginger, Ashwagandha, Senna, Gentiana, Kalmegh, Sarpagandha, Mulhathi, Aconitum species or any other important species relevant to the region.

VII. Suggested Reading

- Atul CK and Kapur BK. 1982. Cultivation and Utilization of Medicinal Plants.RRL, CSIR, Jammu-Tawi.
- Chopra AK. 2007. Medicinal Plants: Conservation, Cultivation and Utilization. Daya Books. Chopra RN, Nayar SL and Chopra IC. 1956. Glossary of Indian Medicinal Plants. CSIR, NewDelhi.
- Cunningham A. 2014. Applied Ethnobotany: "People, Wild Plant Use and Conservation". Taylor & Francis.
- Cupp J and Tracy TS. 2003. Dietary Supplements: Toxicology and Clinical Pharmacology. Humana Press.
- Gunther E. 1975. The Essential Oils. Robert, K Krieger Pub. Co, New York.
- Gupta K, Tandon N and Sharma M. 2008. Quality Standards of Indian Medicinal Plants. Jain SK. 1968. Medicinal Plants. National book trust, New Delhi. Oxford & IBH, New Delhi. Khan IA and Khanum A. 2005. Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health. 1st Ed. Ukaaz Publications.
- Maheshwari JK. 2000. Ethnobotany and Medicinal Plants of Indian Subcontinent. Scientific Publishers,Jodhpur, India.
- Muralia S. 2006. Medicinal and Aromatic Plants. 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	History and scope of pharmacognosy	1
2.	Pharmaceutical products. Classification of natural drugs. Chemical nature of drugs	3
3.	Pharmacognostic analysis of drug plants based on botanical, chemical and histological features	4
4.	Evaluation based on pharmacopoeial standards for both single drugs and compound formulations most commonly used in different systems of medicines	3
5.	Pharmacognostic features of Sarpagandha, Jatamansi, Ashwagandha, Turmeric, Punarnava, Ephedra, Gymnema, Senna, Amla, Gokhru, Isabgol, Black pepper, Banafsha, Arjun or any other commercially species specific to the region	5
	Total	**16**

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Identification of drugs by morphological characters	3
2.	Physical and chemical tests for evaluation of drugs	6
3.	Gross anatomical studies of Ginger, Ashwagandha, Senna, Gentiana, Kalmegh, Sarpagandha, Mulhathi, Aconitum species or any other important species relevant to the region	7
	Total	**16**

M.Sc. (Hort.)

POST-HARVEST MANAGEMENT

Course Title with Credit Load

Course Code	Course Title	Credit Hours
PHM 501	Postharvest Management of Horticultural Produce	3(2+1)
PHM 502	Postharvest Physiology and Biochemistry of Perishables	3(2+1)
PHM 503	Packaging and Storage of Fresh Horticultural Produce	2(1+1)
PHM 504	Packaging and Storage of Processed Horticultural Produce	2(1+1)
PHM 505	Principles and Methods of Fruit And Vegetable Preservation	3(2+1)
PHM 506	Laboratory Techniques in Postharvest Management	3(1+2)
PHM 507	Processing of Horticultural Produce	4(2+2)
PHM 508	Quality Assurance, Safety and Sensory Evaluation of Fresh and Processed Horticultural Produce	3(2+1)
PHM 509	Functional Foods from Horticultural Produce	2(2+0)
PHM 510	Marketing and Entrepreneurship in Postharvest Horticulture	2(1+1)

Course Contents
Post-Harvest Management

I. Course Title : Postharvest Management of Horticultural Produce

II. Course Code : PHM 501

III. Credit Hours : 3(2+1)

IV. Why this course ?

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

V. Aim of the course

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

The course is organized as follows:

No	Blocks		Units
1	Postharvest management of	I	Importance and scope horticultural produce
		II	Regulation of ripening
		II	Treatments for extending shelf life
		IV	Handling system and marketing of horticultural crops

VI. Theory

Block 1: Postharvest Management of Horticultural Produce

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

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

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

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

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

VII. Practical

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

VIII. Teaching Methods/ Activities

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

IX. Learning outcome

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

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

X. Suggested Reading

- Bhattacharjee SK and Dee LC. 2005. Postharvest technology of flowers and ornamental plants. Pointer publishers, Jaipur.
- Chattopadhyay SK. 2007. Handling, transportation and storage of fruit and vegetables. Gene-Tech books, New Delhi
- FAO. 2007. Handing and Preservation of Fruits and Vegetables by Combined methods for Rural Areas-Technical Manual. FAO Agr.Ser.Bull., 149.
- Kader AA. 1992. Postharvest technology of horticultural crops. 2nd ed university of California.
- Paliyath G, Murr DP, Handa AK and Lurie S. 2008. Postharvest Biology and Technology of Fruits, Vegetables and Flowers, Wiley-Blackwell, ISBN: 9780813804088.
- Pruthi JS. 2001 (Reprint). Major spices of India crop management and Postharvest technology. ICAR, NewDelhi
- Stawley J Kays. 1998. Postharvest physiology of perishable plant products. CBS publishers.

- Sudheer KP, Indira V. 2007. Postharvest Technology of Horticultural Crops, Peter K.V. (Ed.), New India Publishing Agency, ISBN 9788189422431.
- Sunil Pareek (Ed.) 2016. Postharvest Ripening Physiology of Crops, CRC Press, ISBN 9781498703802.
- Thompson AK. (Ed.) 2014. Fruit and Vegetables: Harvesting, Handling and Storage (Vol. 1 & 2) Blackwell Publishing Ltd, OXford, UK. ISBN: 9781118654040.
- Verma LR and Joshi VK. 2000. Postharvest Technology of Fruits and Vegetables: Handling, Processing, Fermentation and Waste Management. Indus Publishing Company, New Delhi, India. ISBN 8173871086.
- Wills RBH and Golding J. 2016. Postharvest: an introduction to the physiology and handling of fruit and vegetables, CABI Publishing, ISBN 9781786391483.
- Wills RBH and Golding J. 2017. Advances in Postharvest Fruit and Vegetable Technology, CRC Press, ISBN 9781138894051.

Websites :

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

I. Course Title : Postharvest Physiology and Biochemistry of Perishables

II. Course Code : PHM502

III. Credit Hours : 3(2+1)

IV. Why this course?

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

V. Aim of the course

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

The course is organized as follows:

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

VI. Theory

Block 1: Biochemistry of perishables

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

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

Block 2:Postharvest physiology of perishables

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

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

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

VII. Practical

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

VIII. Teaching Methods/ Activities

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

IX. Learning outcome

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

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

X. Suggested Reading

- Chadha KL and Pal RK. 2015. Managing postharvest quality and losses in horticultural crops. Vol-1: General Issues, 1-231p Astral International (P) Ltd., New Delhi
- Chadha KL and Pal RK. 2015. Managing postharvest quality and losses in horticultural crops. Vol-2: Fruit Crops, 253-561p Astral International (P) Ltd., New Delhi
- Chadha KL and Pal RK. (2015) Managing postharvest quality and losses in horticultural crops. Vol-3: Vegetables, Flowers and Plantation Crops, 581-727p Astral International (P) Ltd., New Delhi
- Hodges DM. 2003. Postharvest Oxidative Stress in Horticultural Crops, 1st Edition, ISBN 9781560229636
- Paliyath G, Murr DP, Handa AK and Lurie S. 2008. Postharvest Biology and Technology of Fruits, Vegetables and Flowers, Wiley-Blackwell, ISBN: 9780813804088.
- Sunil Pareek (Ed.) 2016. Postharvest Ripening Physiology of Crops,CRC Press, ISBN 9781498703802.
- Thompson AK. 1995. Post harvest Technology of fruits and vegetables. Blackwell Sciences
- Verma LR and Joshi VK. 2000. Postharvest Technology of Fruits and Vegetables: Handling, Processing, Fermentation and Waste Management. Indus Publishing Company, New Delhi, India. ISBN 8173871086.
- Wills RBH and Golding J. 2017. Advances in Postharvest Fruit and Vegetable Technology, CRC Press, ISBN 9781138894051.
- Wills RBH and Golding J. 2016. Postharvest: an introduction to the physiology and handling of fruit and vegetables, CABI Publishing, ISBN 9781786391483.

Websites

- Food and Agriculture Organization http://www.fao.org/home/en/
  Respiration in plants http://ncert.nic.in/ncerts/l/kebo114.pdf
- Ethylene biosynthesis and its response http://www.biologydiscussion.com/plants/hormones- plants/ethylene-biosynthesis-and-its-responses-plant-hormones/25986

I. Course Title : Packaging and Storage Offresh Horticultural Produce

II. Course Code : PHM 503

III. Credit Hours : 2(1+1)

IV. Why this course ?

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

V. Aim of the course

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

The course is organized as follows :

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

VI. Theory

Block 1: Storage Systems

Unit I

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

Unit II

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

Unit III

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

Block 2: Packaging

Unit I

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

Unit 2

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

VII. Practical

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

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

VIII. Teaching Methods/ Activities

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

IX. Learning outcome

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

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

X. Suggested Reading

- Ahvenainen R. 2003. Novel Food Packaging Techniques, CRC Press, ISBN 0849317894. Ahvenainen R. 2001. Novel Food Packaging Techniques. CRC.
- Burg SP (Ed.). 2004. Postharvest physiology and hypobaric storage of fresh produce, CABI Publishing, ISBN 0851998011.
- Chattopadhya SK. 2007. Handling, transportation and storage of fruits and vegetables. Gene-Tech books, New Delhi.
- Chandra GopalaRao. 2015. Engineering for Storage of Fruits and Vegetables; Academic Press, 1st Edition.
- Coles R, McDowell D and Kirwan MJ. (Eds.). 2003. Food Packaging Technology, Blackwell Publishing, ISBN 1841272213.
- Mahadevaiah M and Gowramma RV. 1996. Food packaging materials. Tata McGraw Hill.
- Painy FA. 1992. A handbook of food packaging. Blackie Academic.
- Pantastico B. 1975. Postharvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables. AVI Publ.
- Robertson GL. (Ed.). 2010. Food packaging and shelf life: a practical guide CRC Press, ISBN 9781420078442.

- Thompson AK. 2010. Controlled atmosphere storage of fruits and vegetables (2nd Edition), CABI International, ISBN 9781845936464.
- Wilson CL. (Ed.). 2007. Intelligent and active packaging for fruits and vegetables, CRC Press, ISBN 9780849391668.

Websites

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

I. Course Title : Packaging of Processed Horticultural Produce

II. Course Code : PHM 504

III. Credit Hours : 2(1+1)

IV. Why this course ?

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

V. Aim of the course

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

The course is organized as follows :

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

VI. Theory

Block 1: Packaging principles and functions

Unit I:

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

Unit II:

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

Unit III:

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

Unit IV:

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

Unit V:

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

VII. Practical

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

VIII. Teaching Methods/ Activities

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

IX. Learning outcome

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

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

X. Suggested Reading

- Ahvenainen R. 2001. Novel Food Packaging Techniques.CRC
- Ahvenainen R. 2003. Novel Food Packaging Techniques, CRC Press, ISBN 0849317894.
- Coles R, McDowell D and Kirwan MJ. (Eds.) 2003. Food Packaging Technology, Blackwell Publishing, ISBN 1841272213.
- Joseph H Hotchkiss. 1987. Food and Packaging Interactions, (ACS symposium series -365, April 5-10, 1987. American Chemical Society, Washington DC. 1988)
- Mahadevaiah M and Gowramma RV. 1996. Food packaging materials. Tata McGraw Hill.
- Painy FA. 1992. A handbook of food packaging. Blackie Academic.

- Robertson G. L. Ed. 2010. Food packaging and shelf life: a practical guide CRC Press, ISBN 9781420078442.
- Thompson AK. 2010. Controlled Atmosphere Storage of Fruits and Vegetables, CABI Publish ing; 2nd revised edition.
- Wilson CL. (Ed.). 2007. Intelligent and active packaging for fruits and vegetables, CRC Press, ISBN 9780849391668.

I. Course Title : Principles and Methods of Fruit and Vegetable Preservation

II. Course Code : PHM 505

III. Credit Hours : 3(2+1)

IV. Why this course ?

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

V. Aim of the course

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

VI. Learning outcome

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

- Understand Principles and different methods of preservation
- Principal spoilage organisms, food poisoning and their control measures
- Canning of fruits and vegetables
- Processing equipments and layout of processing industry

VII. Theory

Block 1: Principles and Methods of Fruit and Vegetable Processing

Unit I:

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

Unit II:

Thermal processing, pH classification of foods, heat resistance of microorganism; Heat resistance of enzymes in foods, Spoilage of thermal processed food; Containers – canning, rigid tin plates and cans, aluminium cans, glass containers – types; flexible packaging materials, Composite can, specification, corrosion of cans, heat penetration into containers and methods for determination of process time.

Unit III :

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

Unit IV :

Food fermentation – alcoholic, acetic and lactic fermentation. Pickling and curing; Effect of salt on food preservation, types of salt cured products. Traditional and new products; chemical preservation, SO2, benzoic acid, sorbic acid, antioxidants and antibiotics, newer preservatives. Preservation by controlling water activity – high sugar products, intermediate moisture food, food concentration.

Unit V :

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

VII. Practical

- List and cost of equipment, utensils, and additives required for small scale processing industry;
- Chemical analysis for nutritive value of fresh and processed fruits and vegetables;
- Preparation and preservation of fruit based beverages and blended products from fruits and vegetables;
- Evaluation of pectin grade; preparation and quality evaluation of fruit jam;
- Preparation of papain;
- Blanching and its effects on enzyme;
- Preparation of dehydrated vegetables;
- Study of different types of spoilages in fresh as well as processed horticultural produce;
- Study of biochemical changes and enzymes associated with spoilage;
- Sensory evaluation of fresh and processed fruits and vegetables;
- Visit to processing units.

VIII. Teaching Methods/ Activities

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

IX. Suggested Reading

- Barret DM, Somogyi LP and Ramaswamy H. Eds. 2005. Processing Fruits: Science and Tech nology (2nd Edition), CRC Press, ISBN 9780849314780.
- FAO. 2007. Handling and Preservation of Fruits and Vegetables by Combined Methods for Rural Areas- Technical Manual. FAO Agricultural Services Bulletin 149.
- Fellows PJ. 2009. Food Processing Technology: Principles and Practice (3rd Edition), Woodhead Publishing, ISBN 9781845692162.
- Lal G, Siddappa GS and Tandon GL. 1998. Preservation of Fruits and Vegetables. ICAR, ISBN 9788171640904.

- Ramaswamy H and Marcotte M. 2006. Food Processing: Principles andApplications. Taylor & Francis.
- Salunkhe DK and Kadam SS. 1995. Handbook of Fruit Science and Technology:Production, Composition and Processing. Marcel Dekker.
- Srivastava RP and Kumar S. 2014. Fruit and Vegetable Preservation: Principles and Practices (3rd Edition), CBS Publishing, ISBN 9788123924373.
- Verma LR and Joshi VK. 2000. Postharvest Technology of Fruits and Vegetables: Handling, Processing, Fermentation and Waste Management. Indus Publishing Company, New Delhi, India. ISBN 8173871086.

Websites

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

I. Course Title : Laboratory Techniques in Postharvest Horticulture
II. Course Code : PHM 506
III. Credit Hours : 3(1+2)
IV. Why this course ?

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

V. Aim of the course

To familiarise with advances in instrumentation and Postharvest management

VI. Theory

Block 1: Laboratory Techniques in Postharvest Management

Unit I:

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

Unit II:

Analysis of pesticide residues, metallic contaminants, aflatoxin Analysis of food flavours.

Unit III:

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

Unit IV:

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

Unit V:

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

VII. Practical

- Sample preparation for quality analysis. Energy calculation, sample calculations;
- Texture analysis, Rheology of different foods;
- Instrumental colour analysis;
- Sensory evaluation and microbiological examinations of fresh and processed products;
- Estimation of tannin/ phytic acid by spectrometric method;
- Moisture and fat analysis by NIR spectroscopy;
- Separation and identification of sugars in fruit juices;
- Separation and identification of carotenoids by column chromatography;
- Estimation of respiration in fruits and vegetables;
- Flavour profile in essential oils using GC;
- Identification and determination of organic acids by HPLC;
- Capsaicin content and Scoville Heat Units in chillies;
- Heavy metal analysis using atomic absorption spectrometry;
- Residue analysis.

VIII. Teaching Methods/ Activities

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

IX. Learning outcome

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

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

X. Suggested Reading

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

I. **Course Title : Processing of Horticultural Produce**

II. **Course Code : PHM 507**

III. **Credit Hours : 4(2+2)**

IV. Why this course ?

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

V. Aim of the course

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

This course is organized as follows:

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

VI. Theory

Block 1: Importance and Thermal processes

Unit I:

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

Unit II:

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

Unit III:

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

Block 2 : Processing equipment and enzyme kinetics

Unit I :

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

Unit II:

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

VII. Practical

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

VIII. Teaching Methods/ Activities

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

IX. Learning outcome

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

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

X. Suggested Reading

- Karel M and Lund DB. 2003. Physical Principles of Food Preservation (2nd Edition), CRC Press, ISBN 9780824740634.
- Paul Singh R and Heldman DR. 2009. Introduction to Food Engineering (4th Edition), Academic Press, ISBN 9780123709004.
- Rao DG. 2010. Fundamentals of Food Engineering, PHI Learning Pvt. Ltd., ISBN 9788120338715.
- Ratti C. 2008. Advances in Food Dehydration, CRC Press, ISBN 9781420052527.
- Toledo RT. 2007. Fundamentals of Food Process Engineering (3rd Edition), Springer, ISBN 9780387290195.
- Smith PG. 2011. Introduction to Food Process Engineering, Springer, ISBN 9781441976611.

I. Course Title : Quality Assurance, Safety and Sensory Evaluation of Fresh and Processed Horticultural Produce

II. Course Code : PHM 508

III. Credit Hours : 3(2+1)

IV. Why this course ?

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

V. Aim of the course

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

This course is organized as follows:

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

VI. Theory

Block 1: Quality Assurance

Unit I:

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

Unit II:

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

Block 2: Safety

Unit I :

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

Unit II:

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

Block 3: Sensory Evaluation

Unit I:

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

Unit II:

Methods of sensory evaluation of different food products. Designing of experiments. Handling and interpretation of Data. Role of sensory evaluation in product optimization. Relationship between objective and subjective methods. Sensory analysis for consumer evaluation. Computer-aided sensory evaluation of food and beverage.

VII. Practical

- Analysis for TSS, pH, acidity, sugars, pectic substances, minerals, vitamin C, carotene, alcohol, benzoic acid and SO_2 contents, yeast and microbial examination in processed products;
- Demonstration of measurement of vacuum/ pressure, head space, filled weight, drained weight, cut-out analysis and chemical additives;
- Moisture content, rehydration ratio and enzymatic/ non-enzymatic browning in dehydrated prod ucts;
- Analysis of spices for quality parameters. Evaluation of processed products according to FSSAI specification;
- Selection and training of sensory panel;
- Identification of basic taste, odour, texture and colour;
- Detection and threshold tests; Ranking tests for taste, aroma, colour and texture; Sensory evalu ation of various horticultural processed products using different scales, score cards and tests, Hedonic testing;
- Estimation of color and texture; optimising a product by sensory analysis;
- Studying relationship between objective and subjective methods.

VIII. Teaching Methods/ Activities

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

IX. Learning outcome

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

- Concepts of quality management

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

X. Suggested Reading

- Amerine MA, Pangborn RM and Rosslos EB. 1965. Principles of Sensory Evaluation of Food. Academic Press.
- Curtis PA. 2005. Guide to Food Laws and Regulations, Wiley-Blackwell, ISBN 9780813819464.DGHS Manual 8: Manual of Methods of Analysis of Foods-Food Additives.
- Curtis PA. 2005. Guide to Food Laws and Regulations, Wiley-Blackwell, ISBN 9780813819464. Early R. 1995. Guide to Quality Management Systems for the Food Industry, Springer, ISBN 9781461358879.
- Kemp SE, Hollowood T and Hort J. 2009. Sensory Evaluation: A Practical Handbook, Wiley-Blackwell Publisher, ISBN 9781405162104.
- Krammer A and Twigg BA. 1973. Quality Control in Food Industry.Vol.I, II.AVI Publ.
- Lawless, Harry T, Heymann and Hildegarde. 2010. Sensory Evaluation of Food: Principles and Practices, Springer, ISBN 9781441964885.
- Ranganna S. 2001. Handbook of Analysis and Quality Control for Fruit and Vegetable Products, Tata McGraw-Hill ISBN 9780074518519.
- Ranganna S. 2001. Handbook of Analysis and Quality Control for Fruit and Vegetable Products, Tata McGraw-Hill, ISBN 9780074518519.
- The Food Safety and Standards Act, 2006 along with Rules & Regulations 2011, Commercial Law Publishers (India) Pvt. Ltd.

Websites

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

I. Course Title : Functional Foods from Horticultural Produce

II. Course Code : PHM 509

III. Credit Hours : 2(2+0)

IV. Why this course ?

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

V. Aim of the course

To familiarise with functional foods from horticultural produce

This course is organized as follows:

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

VI. Theory

Block 1: Functional food and importance

Unit I:

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

Unit II:

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

Block 2: Bioactive Compounds

Unit I:

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

Unit II:

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

Block 3: Neutraceuticals

Unit I:

Nutraceuticals- Introduction, classification of nutraceuticals, dietary supplements, fortified foods, functional foods and phytonutraceuticals. Role of medicinal and aromatic plants in nutraceutical industry. Health benefits of phytoneutraceuticals.

VII. Teaching Methods/ Activities

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

VIII. Learning outcome

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

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

IX. Suggested Reading

- Rosa LA, Alvarez-Parrilla E and Gonzalez-Aguilar GA. 2009. Fruit and Vegetable Phytochemicals: Chemistry, Nutritional Value and Stability, Wiley-Blackwell, ISBN 9780813803203.
- Senrawat R, Khan KA, Goyal MR and Paul PK. 2018. Technological Interventions in the Processing of Fruits and Vegetables, Apple Academic Press, ISBN 9781771885867.
- Vattem DA. 2016. Functional Foods, Nutraceuticals and Natural Products: Concepts and Ap plications. DEStech Publications, Inc, ISBN 978 1 60595 101 0.
- Watson RR and Preedy V. 2009. Bioactive Foods in Promoting Health: Fruits and Vegetables (1st Edition), Academic Press, ISBN 9780123746283

I. Course Title : Marketing and Entrepreneurship in Post Harvest Horticulture

II. Course Code : PHM 510

III. Credit Hours : 2(1+1)

IV. Why this course ?

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

V. Aim of the course

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

This course is organized as follows:

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

VI. Theory

Unit I:

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

Unit II:

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

Unit III:

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

Unit IV:

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

Unit V:

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

VII. Practical

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

VIII. Teaching Methods/ Activities

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

IX. Learning outcome

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

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

X. Suggested Reading

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

M.Tech. in

Agricultural Engineering

Course Title with Credit Load

Farm Machinery and Power Engineering

Course Code	Course Title	Credit Hours
FMPE 502	Testing and Evaluation of Agricultural Equipment	3(2+1)
FMPE 503	Ergonomics and Safety in Farm Operations	3(2+1)
FMPE 507	Management of Farm Power and Machinery System	3(2+1)
FMPE 517	Machinery for Precision Agriculture	3(2+1)
FMPE 518	Machinery for Horticulture and Protected Agriculture	2(2+0)

Course Contents

Farm Machinery and Power Engineering

I. Course Title : Testing and Evaluation of Agriculture Equipment

II. Course Code : FMPE 502

III. Credit Hours : 3(2+1)

IV. Aim of the course

To enable the student to learn the procedure for testing of different farm machinery and the concept behind evaluation of different performance parameters of farm machinery and the standards adopted therein.

V. Theory

Unit I

Importance and significance of testing and types of testing. Test equipment, usage and limitations. Test procedures and various test codes: National and International.

Unit II

Laboratory and field testing of tillage and sowing machinery: Sub-soiler, laser land leveler, mould board Plough, disc plough, rotavator, cultivator, disc harrow, seed cum fertilizer drill and planter.

Unit III

Laboratory and field testing of manual and power operated intercultural machinery and plant protection machine.

Unit IV

Laboratory and field testing of reaper, thresher and chaff cutter.

Unit V

Laboratory and field testing of straw combine and combine harvester. Review and interpretation of test reports. Importance and need of standardization of components of agricultural equipment.

VI. Practical

Laboratory and field testing of selected farm equipment: Tillage, sowing and planting. Material testing of critical components. Accelerated testing of fast wearing components.

VII. Learning outcome

The student will be able to test farm machinery, prepare performance reports and also analyze the performance reports to find the suitability of a machinery for a given farm operation.

VIII. Lecture Schedule

S.No	Topic	No. of Lectures
1.	Introduction, various test codes, Test programs, testing terminology, procedures and type of testing systems	2
2.	Study of different types of Dynamometer	2
3.	Stationary diesel engine performance testing	2
4.	Tractor Test Codes and Data Interpretation Estimation of error	2
5.	Testing and evaluation of tillage machinery	2
6.	Testing and evaluation of seed-cum-fertilizers drills/planters	3
7.	Testing and evaluation of manually and power operated Sprayers	3
8.	Testing and evaluation of reapers and straw combines	1
9.	Testing and evaluation of combine harvester and threshers	3
10.	Testing and evaluation of manually and power operated chaff cutters	2
11.	Testing and evaluation of advanced machinery	2
12.	Reliability in Engineering with emphasis on agricultural machinery	2
13.	Discussion on Farm machinery codes	2
14.	Interpretations of the information given in different codes on farm machinery	1
15.	Formulation of test-code for machines that do not have any code.	2
16.	Current topics/discussion	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Lab testing of Stationary diesel engine for full load, variable load and governor test	2
2.	Lab Testing and evaluation of seed-cum-fertilizers drills	1
3.	Lab Testing and evaluation of seed-cum-fertilizers planters	1
4.	Lab Testing and evaluation of knapsack Sprayers	1
5.	Lab Testing and evaluation of nozzles	1
6.	Field testing of rotavators	1
7.	Lab testing of rotavators for soil sample analysis	1
8.	Testing and evaluation of reapers	1
9.	Testing and evaluation of combine harvester and threshers	1
10.	Testing and evaluation of chaff cutters	1
11.	Testing and evaluation of laser land leveler	1
12.	Case study of test reports of different agricultural implements	3
	Total	**15**

X. Suggested Reading

- Barger E L, Liljedahl J B and McKibben E C. 1967. Tractors and their Power Units. Eastern Wiley 4th Edition.
- Indian Standard Codes for Agricultural Implements. Published by BIS, New Delhi.
- Inns F M. 1986. Selection, Testing and Evaluation of Agricultural Machines and Equipment. FAO Service Bull. No.115.

- Mehta M L, Verma S R, Rajan P and Singh S K 2019. Testing and Evaluation of Agricultural Machinery. Daya Publishing House, Delhi.
- Nebraska Tractor Test Code for Testing Tractor, Nebraska, USA.
- Smith D W, Sims B G and O'Neill D H 2001. Testing and Evaluation of Agricultural Machinery and Equipment -Principle and Practice. FAO Agricultural Services Bull. 110.

I. Course Title : Ergonomics and Safety in Farm Operations

II. Course Code : FMPE 503

III. Credit Hours : 3(2+1)

IV. Aim of the course

To understand the principles of the science of Ergonomics and its application to farm machinery in order to reduce drudgery in the use of tools and equipment and also make them safe and comfortable to operate.

V. Theory

Unit I

Description of human-machine systems. Ergonomics and its areas of application in the work system. History of ergonomics. Modern ergonomics.

Unit II

Anthropometry: Its role in daily life, principles in workspace and equipment design, design of manual handling tasks and application in equipment design. Human postures: Postural stress and its role in design of farm machinery.

Unit III

Human factors in tractor seat design: Entry system, controls, shape, colour coding, dial and indicators. Modern technology for comfort in driving places.

Unit IV

Physiological parameters: Psychological and mental stresses and their measurement techniques. Human energy expenditure: Calibration of subjects, human workload and its assessment.

Unit V

Safety considerations and operators protective gadgets in farm operations. Standards/codes for tractors and agricultural machinery safety.

VI. Practical

Identifying role of ergonomics in our daily life. Measurement of anthropometric dimensions of agricultural workers and establishing relationship between them. Determination of human requirements for field operation with manually operated equipment. Assessment of psychological/general load for specific agricultural operations. Calibration of human subject on bicycle ergometer and/ or treadmill for its energy output and physiological parameters like heart rate, oxygen consumption rate under laboratory conditions. Case studies of agricultural accidents and safety measure.

VII. Learning outcome

The student will be able to apply the concepts of ergonomics in the design of agricultural tools and equipment and also evaluate the ergonomic suitability of such equipment.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to ergonomics, definition of ergonomics	1
2.	Operator- machine-environment system approach	1
3.	Relative advantages of man and machine, ergonomics in daily life	1
4.	Importance of ergonomics in agriculture and farm machinery	1
5.	History of ergonomics, modern ergonomics	1
6.	Man machine environment components, broad objectives of ergonomics	1
7.	Basic issues and processes under ergonomics for design and development of machine	1
8.	Anthropometry and its uses in daily life	1
9.	First hourly examination	1
10.	Principles of applied anthropometry in ergonomics	1
11.	Availability of anthropometric database for Indian agricultural workers	1
12.	Definitions and possible applications of anthropometric dimensions	2
13.	Workspace and equipment design	1
14.	Different modes of force application	1
15.	Design of manual handling tasks	1
16.	Biomechanics aspects in machine design	1
17.	Mid-semester examination	1
18.	Human posture, posture stresses and its role in design of agricultural machinery	1
19.	Work place design for standing and seated workers	2
20.	Human factors in tractor seat design	1
21.	Entry system, controls, shape, colour coding, dial and indicators	1
22.	Modern technology for safety and comfort in driving place	1
23.	Physiological and psychological parameters for ergonomic evaluation	1
24.	Physiological and psychological stresses and measurements techniques	1
25.	Human work load assessment, human energy expenditure	1
26.	Calibration of subjects – concept, importance and techniques	1
27.	Accidents and safety in agriculture operations, general safety guidelines	1
28.	Safety feeding systems for threshers and chaff cutters	1
29.	Safety gadgets for tractors and trailers	1
30.	Standard/ codes for agricultural machinery safety	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Identify role of ergonomics in our daily life	1
2.	Measurement of anthropometric dimensions of agriculture workers and establishing relation between them	2
3.	Measurement of strength parameters	1
4.	Determination of human requirements of field operation with manual operated equipment	2
5.	Assessment of psychological/ general load for agricultural operations	1
6.	Assessment of stress on eyes by specific agricultural operation	1
7.	Noise measurement in tractors	1
8.	Calibration of human subject on bicycle ergometer	1
9.	Calibration of human subject on treadmill	1
10.	Measurement of physiological parameter, viz. heart/ pulse rate	1
11.	Measurement of oxygen consumption under laboratory conditions	1
12.	Case study of accidents and safety on tractors and trailers	1
13.	Case study of accidents and safety on chaff cutters and threshers	1
14.	Practical examination	1
	Total	**16**

X. Suggested Reading

- Bridger R S 2009. Introduction to Ergonomics. CRC Press, Boca Rotan, USA
- Sanders M S and McCormick E J 2000. Human Factors in Engineering and Design. McGraw Hill. 7th edition
- Astrand P, Rodahl K, Dahl H A and Stromme S B 2003. Textbook of Work Physiology - Physiological Basis of Exercise. McGraw Hill.
- Gite L P 2009. Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design. Central Institute of Agricultural Engineering, Bhopal.
- Gite L P, Agrawal K N, Mehta C R, Potdar R R and Narwariya B S. 2019. Handbook of Ergonomical Design of Agricultural Tools, Equipment and work Places. Jain Brothers, New Delhi.

I. Course Title : Management of Farm Power and Machinery System

II. Course Code : FMPE 507

III. Credit Hours : 3(2+1)

IV. Aim of the course

To understand how principles of management are applied to farm machinery systems to make them more effective and profitable.

V. Theory

Unit I

Importance and objectives of farm mechanization in Indian agriculture, its impact, strategies, myths and future needs. Estimation of operating cost of tractors and farm machinery. Management and performance of power, operator, labour. Economic performance of machinery, field capacity, field efficiency and factors affecting field efficiency.

Unit II

Tractor power performance in terms of PTO, drawbar and fuel consumption. Power requirement problems to PTO, DBHP.

Unit III

Selection of farm machinery, size selection, timeliness of operation, optimum width and problem related to its power selection. Reliability of agricultural machinery. Replacement of farm machinery and inventory control of spare parts.

Unit IV

Systems approach to farm machinery management and application of programming techniques to farm machinery selection and scheduling. Network Analysis: Transportation, CPM and PERT, dynamic programming, Markov chain.

VI. Practical

Study of latest development of different agricultural equipment and implements in India and other developing countries. Size selection of agricultural machinery. Experimental determination of field capacity of different farm machines. Study of farm mechanization in relation to crop yield. Determination of optimum machinery system for field crop and machine constraints. To develop computer program for the selection of power and machinery.

VII. Learning outcome

The student will be able to understand how farm machinery is selected and operated to make them economically viable.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Importance and scope of farm mechanization in Indian Agriculture	1
2.	Cost analysis of Farm Machinery and tractor, Breakdown analysis, Inflation.	2
3.	Measurement of power performance (PTO power, drawbar power and fuel consumption) of tractor and power tiller	3
4.	Study of field capacity and field efficiency of different farm machinery and factor affecting them	1
5.	Selection of Farm Machinery size wrt to power source and timeliness of operation	4
6.	Application of programming technique to problem of farm power and machinery selection.	4
7.	Replacement models, spare parts and inventory control	2
8.	Maintenance and scheduling of operations.	2
9.	Network analysis – transportation	2

10.	Network analysis – critical path method, PERT	2
11.	Network analysis – dynamic programming	3
12.	Network analysis – markov chain	3
13.	Linear programming, multivariable system, simplex algorithm. Theory of network.	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1.	Introduction to latest development of advanced agricultural equipment's in India	3
2.	Experimental determination of field capacity of different farm machines	3
3.	Case studies on optimum size selection of agricultural machinery	3
4.	Determination of inventory of different farm machines for a farm of size 50 ha as per regional crop rotations	3
5.	To develop computer program regarding selection of farm machinery size and power requirement for a 10, 50 and 100 ha farm size	3
	Total	**15**

X. Suggested Reading

- Carveille LA. 1980. Selecting Farm Machinery. Louisiana Cooperative EXtn. Services Publica tion.
- Culpin C. 1996. Profitable Farm Mechanization. Lock Wood and Sons, London.
- FAO. 1990. Agricultural Engineering in Development: Selection of Mechanization Inputs. FAO, Agri service Bulletin.
- Hunt D. 1979. Farm Power and Machinery Management. Iowa State University Press, USA.
- Kapoor VK. 2012. Operation Research: Concepts, Problems and Solutions. Sultan Chand and Sons, India.
- Singh S and Verma SR. Farm Machinery Maintenance and Management. DIPA, ICAR, KAB-I, New Delhi.

I. Course Title : Machinery for Precision Agriculture

II. Course Code : FMPE 517

III. Credit Hours : 3(2+1)

IV. Aim of the course

To learn the principles behind precision agriculture and the systems for implanting the same.

V. Theory

Unit I

Importance of precision agriculture. Mapping in farming for decision making. Geographical concepts of PA.Understanding and identifying variability

Unit II

Geographical Position System (GPS) Basics (Space Segment, Receiver Segment, Control Segment), Error and correction, Function and usage of GPS. Introduction to Geographic Information system (GIS), function of GIS, use of GIS for decisions. IDI devices usage in Precision Agriculture Yield monitor, variable rate applicator for fertilizers, seed, chemicals etc. Remote sensing Aerial and satellite imagery. Above ground (non-contact) sensors.

Unit III

Data analysis, concepts of data analysis, resolution, Surface analysis. Analysis application interpretive products (map, charts, application map etc).

Unit IV

Electronics and Control Systems for Variable rate applications, Precision Variable Equipment, Tractor-Implement interface technology, Environmental Implications of Precision Agriculture.

Unit V

Goals based on end results of Precision Agriculture, Recordkeeping, Spatial Analysis, Variable Rate Application, Reducing of negative environmental impact, Crop/ technology cost optimization. Economic of precision agriculture and determining equipment and software, review of Cost/Benefit of Precision Agriculture, System vs. Parcels. Making a selection.

VI. Practical

Calculation of the benefits of Data and Mapping, Determining Latitude/Longitude, UTM or State Plane Position Navigation with Waypoints, Configuring a GPS System. Defining area of field for prescriptive treatment. Making the Grid, The Grid Sampling Process, generation of yield maps, Thematic or Spatial Resolution, Yield Map Example, Surface Analysis in Arc-View.

VII. Learning outcome

Knowledge about the principles guiding the concept of precision agriculture and Farm Machinery and equipment systems that make muse of this principle.

VIII. Lecture Schedule

S.No.	Topic	No of Lectures
1.	Introduction to precision agriculture, its importance and applications	1
2.	Mapping in farming for decision making and geographical concepts of PA.	2
3.	Understanding and identifying variability	1
4.	Introduction to Geographical Position System (GPS). Function and usage of GPS	2
5.	Basics of GPS (Space Segment, Receiver Segment, Control Segment), Error and correction	2
6.	Introduction to Geographic Information system (GIS), function of GIS, use of GIS for decisions.	2
7.	Remote sensing including aerial and satellite imagery	2
8.	IDI devices usage in Precision Agriculture Yield monitor, variable rate applicator for fertilizers, seed, chemicals etc. Above ground (non-contact) sensors	2
9.	Data analysis, concepts of data analysis	3

10.	Surface analysis. Analysis application interpretive products (map, charts, application map etc)	2
11.	Precision Variable Equipment	2
12.	Electronics and Control Systems for variable rate applications	2
13.	Tractor-Implement interface technology, Environmental Implications of Precision Agriculture	2
14.	Recordkeeping, Spatial Analysis	2
15.	Rate Application, reducing of negative environmental impact, Crop/technology cost optimization	2
16.	Economic of precision agriculture and determining equipment	2
17.	Review of Cost/Benefit of Precision Agriculture, Making a selection	2
	Total	**33**

IX. Practical Schedule

S.No.	Topic	No of Practicals
1.	Calculation of the benefits of data and mapping	1
2.	Determining Latitude/Longitude, UTM or State Plane Position Navigation with Waypoints	2
3.	Configuring a GPS System	1
4.	Defining area of field for prescriptive treatment	1
5.	Making the grid and grid sampling process	2
6.	Collection of tractor-implement interface data	1
7.	Generation of yield maps	2
8.	EXample of spatial and temporal variability and resolution	1
9.	Surface Analysis using software like Arc-View	2
10.	Economic of precision agriculture and determining equipment	2
11.	Cost/Benefit of Precision Agriculture for making a optimized selection	2
	Total	**17**

X. Suggested Reading

- Clay SA, Clay DE and Bruggeman SA. 2017. Practical Mathematics for Precision Farming American Society of Agronomy, Crop Science Society and Soil Science Society of America, 5585 Gulford Rd, Madison, WI 53711
- Henten EJV, Goense D and Lokhorst C. 2009. Precision Agriculture. Wageningen Academic Publishers.
- Ram T, Lohan SK, Singh R and Singh P. 2014. Precision Farming: A New Approach. Astral International Pvt. Ltd., New Delhi, ISBN: ISBN 978-81-7035-827-5 (Hardbound) ISBN 978-93-5130-258-2 (International Edition).
- Shannon DK, Clay DE and Kitchen NR (editors). 2018. Precision Agriculture Basics American Society of Agronomy, Crop Science Society and Soil Science Society of America, 5585 Gulford Rd, Madison, WI 53711
- Singh AK and Chopra UK. 2007. Geoinformatics Applications in Agriculture. New India Publishing Agency, PritamPura, New Delhi.

I. Course Title : Machinery for Horticulture and Protected Agriculture

II. Course Code : FMPE 518

III. Credit Hours : 2(2+0)

IV. Aim of the course

To learn about the different machinery used in cultivation of vegetable crops, orchard crops and also in protected agriculture.

V. Theory

Unit I

Vegetable cultivation, nursery machinery, tray seeders, grafting machines, vegetable trans-planters. Machinery for planting crops on raised beds, mulch laying and planting machines. Harvesting of vegetable crops: Harvesting platforms and pickers.

Unit II

Machinery for orchard crops: Pit diggers, inter-cultivators and basin forming equipment for orchards. Machinery for transplanting of trees. Harvesters for fruit crops: Shaker harvesters, types and principle of operation. Elevated platforms for orchard management and harvesting. Pruning machines.

Unit III

Machinery for orchards, vineyard machinery spraying machines, inter-cultivation machines. High clearance machines and special purpose machinery for crops on trellis. Machinery for special crops: Tea leaf harvesters, pruners and secateurs.

Unit IV

Machinery for lawn and garden: Grass cutters, special machinery for turf maintenance. Turf aerators and lime applicators.

Unit V

Protected agriculture: Principles, mechanical systems of greenhouse, ventilation systems, shading system, water fogging system, irrigation system, sensors, electrical and electronic system. Intelligent Control system for greenhouses. Machinery for processing of growth media, tray filling machines-tray sowing machines, transplanting machines. Robotic grafting machines. Weeding and thinning equipment. Crop protection and harvest under protected agriculture.

VI. Learning outcome

Knowledge about different principles of mechanizing cultivation of horticultural crops and in protected agriculture.

VII. Lecture Schedule

S.No.	Topic	No. of Lecture
1.	History of vegetable cultivation in India and scope of mechanization in Horticulture	1
2.	Methods of Nursery propagation techniques and machinery for nursery and tray seeders	1
3.	Machinery for field preparation for vegetables (Disc harrows, Disc plough, offset rotavator, sub soiler, bed makers)	1
4.	Principles of mulch laying and planting machines. Types of vegetable transplanters and their construction and working	1
5.	Working and construction of subsurface drip laying machine.	

	Types of planters for vegetable crops and its working	1
6.	Principles of Pneumatic vegetable seeders and its working. Machinery for harvesting of vegetable crops like root crop harvester, its construction and working	1
7.	Types of vegetable extraction machine, its working and construction	1
8.	Types of pickers, their construction and working	1
9.	Construction and working of different types of post hole diggers	1
10.	Types of tractors and their uses in orchards	1
11.	Types of inter cultivators and its construction and working.	1
12.	Types of brush cutters and its working	1
13.	Types of basin forming equipment for orchards. Machinery for transplanting of trees and their construction and working	1
14.	Types of elevated platforms for orchard management. Types of Tree Pruners and principles and its working and construction	1
15.	Types of fruit pluckers and its working and construction	1
16.	Principles and working and construction of shaker harvesters	1
17.	Types of vineyard machinery and its working and construction	1
18.	Types of spraying machines and its working and construction. High clearance machines and special purpose machinery for crops on trellis.	1
19.	Types of orchard sprayers, its working and construction	1
20.	Types of Tea leaf harvesters, pruners and secateurs and its working and Construction	1
21.	Special purpose machinery for crops on trellis	1
22.	Types of lawn and garden mowers and its working.	1
23.	Studies on special machinery for turf maintenance working and construction of Turf aerators and lime applicators	1
24.	Introduction to protected agriculture. Principles of protected agriculture	1
25.	Greenhouses - Mechanical systems, ventilation systems, shading system, water fogging system and irrigation system.	2
26.	Sensors, electrical and electronic system. Intelligent Control system for greenhouses	1
27.	Machinery for processing of growth media, tray filling machines-tray sowing machines, transplanting machines	1
28.	Robotic grafting machines. Weeding and thinning equipment	1
29.	Crop protection and harvest under protected agriculture	1
	Total	**30**

VIII. Suggested Reading

- Bell B and Cousins S. 1997. Machinery for Horticulture. Old Pond Publishing Ltd ISBN-10: 0852363699,ISBN-13: 978-0852363690
- Good Agricultural Practices for Greenhouse Vegetable Production in the South East European countries FAO Rome 2017.
- Ponce P, Molina A, Cepeda P, Lugo E and MacCleery B. 2014. Greenhouse Design and Control. CRC Press, ISBN 9781138026292 - CAT K23481, 1st Edition.

Course Title with Credit Load

Irrigation and Drainage Engineering

Course Code	Course Title	Credit Hours
IDE 501	Design of Surface Irrigation Systems	2(1+1)
IDE 502	Design of Farm Drainage Systems	3(2+1)
IDE 503	Command Area Management	3(2+1)
IDE 504	Water and Nutrient Management Under Protected	3(2+1)
IDE 505	Design of Drip and Sprinkler Irrigation Systems	3(2+1)
IDE 506	Ground Water Engineering	3(2+1)
SWCE 507/IDE 507	Remote Sensing and GIS for Land and Water Resource	3(2+1)
IDE 508	Waste Water Management and Utilization in Agriculture	3(2+1)
IDE 509	Water Conveyance and Distribution	3(2+1)
IDE 510	Minor Irrigation	3(2+1)
IDE 511	Design of Pumps for Irrigation and Drainage	2(2+0)
IDE 512	Crop Environmental Engineering	2(2+0)
IDE 513	Water Resources Systems Engineering	2(2+1)
IDE 514	Irrigation Economics, Planning and Management	2(2+0)
IDE 515	Sensing and Automation in Irrigation Systems	3(3+0)

Course Contents
Irrigation and Drainage Engineering

I. Course Title : Design of Surface Irrigation Systems

II. Course Code : IDE 501

III. Credit Hours : 2(1+1)

IV. Aim of the course

To acquaint students for design and evaluation of various surface irrigation methods, design optimum layout, conveyance network for efficient use of water in surface irrigation system.

V. Theory

Unit I

Climate and irrigation water requirement. Irrigation principles, losses, conveyance, distribution, application and water budgeting. Estimation techniques of effective rainfall. Irrigation softwares: CROPWAT, AQUACROP.

Unit II

Farm irrigation systems. Irrigation efficiencies. Economic feasibility. Irrigation water quality and salinity management techniques. Design of water conveyance, control and distribution systems.

Unit III

Hydraulics: Design and operation of border, check basin, furrow, sprinkler and trickle irrigation systems. Flow dynamics, drop size distribution and spray losses in sprinklers. Cablegation, surge and bubbler irrigation. Automation of irrigation system.

Unit IV

Basic water management concepts and objectives. Alternative irrigation scheduling techniques. Integrated approach to irrigation water management.

VI. Practical

Design and evaluation of border, furrow, check basin, sprinkler and micro-irrigation. Computation of frictional losses. Design of underground water conveyance systems. Economics of irrigation methods. Visit to mechanized farms.

VII. Learning outcome

The students will be able to plan and design various surface irrigation systems and irrigation scheduling techniques for efficient use of water. They will also be exposed to irrigation softwares used for design purpose.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Climate and irrigation water requirement	1
2.	Irrigation principles, losses, conveyance, distribution, application and water budgeting	2
3.	Estimation techniques of effective rainfall	2

4.	Irrigation softwares; CROPWAT, AQUACROP	2
5.	Farm irrigation systems. Irrigation efficiencies, Economic feasibility	2
6.	Irrigation water quality and salinity management techniques	2
7.	Design of water conveyance, control and distribution systems	2
8.	Hydraulics; Design and operation of border, check basin and furrow irrigation systems.	5
9.	Hydraulics: Design and operation of sprinkler and trickle irrigation systems	4
10.	Flow dynamics, drop size distribution and spray losses in sprinklers	2
11.	Cablegation, surge and bubbler irrigation	3
12.	Automation of irrigation system	2
13.	Basic water management concepts and objectives	2
14.	Alternative irrigation scheduling techniques	1
15.	Integrated approach to irrigation water management	2
	Total	**34**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Estimation of different techniques of effective rainfall	1
2.	Design of irrigation methods using irrigation software's: CROPWAT, AQUACROP	3
3.	Design of water conveyance, control and distribution systems.	1
4.	Design and evaluation of border irrigation method	1
5.	Design and evaluation of furrow irrigation method	1
6.	Design and evaluation of check basin method	1
7.	Design and evaluation of sprinkler irrigation method	1
8.	Design and evaluation of trickle irrigation method	1
9.	Study of automation of irrigation system	1
10.	Design of underground water conveyance systems	1
11.	Study of economics of irrigation methods	2
12.	Visit to mechanized farms	1
	Total	**15**

X. Suggested Reading

- Finkel HJ. 1983. Handbook of Irrigation Technology. Vols. I-II, CRC Press.
- James LG. 1988. Principles of Farm Irrigation System Design. John Wiley and Sons, New York, USA.
- Karmeli D, Peri G and Todes M. 1985. Irrigation Systems: Design and Operation. OXford University Press.
- Michael AM. 2008. Irrigation Theory and Practices. Vikas Publishing House Pvt. Ltd, New Delhi.
- Pillsbury AF. 1972. Sprinkler Irrigation. FAO Agricultural Development Paper No. 88, FAO.
- Rydzewski. 1987. Irrigation Development Planning. John Wiley and Sons.
- Sivanappan RK 1987. Sprinkler Irrigation. OXford and IBH.
- Sivanappan RK, Padmakumari O and Kumar V. 1987. Drip Irrigation. Keerthy Publ, House.

I. Course Title : Design of Farm Drainage Systems

II. Course Code : IDE 502

III. Credit Hours : 3(2+1)

IV. Aim of the course

To provide in depth knowledge of water logging and salt affected areas, surface and sub-surface drainage systems, design and reclamation of salt affected waterlogged areas.

V. Theory

Unit I

Salt affected waterlogged areas in India. Water quality criteria and brackish water use for agriculture. Drainage requirements and crop growth under salt affected waterlogged soil.

Unit II

Concept of critical water table depth for waterlogged soil and crop growth. Drainage investigations and drainage characteristics of various soils. Methods of drainage system and drainage coefficient.

Unit III

Theories and applications of surface and subsurface drainage. Planning, design and installation of surface and subsurface drainage systems for waterlogged and saline soils. Theories and design of vertical drainage, horizontal subsurface drainage and multiple well point system. Drainage materials.

Unit IV

Steady and unsteady state drainage equations for layered and non-layered soils. Principle and applications of Hooghoudt, Kirkham, Earnst, Glover Dumm, Kraijenhoff-van-de-leur equations. Drainage for salinity control.

Unit V

Salt balance, leaching requirement and management practices under drained conditions. Disposal of drainage effluents. Case study for reclamation of salt affected waterlogged areas.

VI. Practical

Measurement of in-situ hydraulic conductivity. Estimation of drainage coefficient and leaching requirements. Delineation of waterlogged areas through isobar, isobath and topographic maps. Design of surface and subsurface drainage systems. Design of filter and envelop materials.

VII. Learning outcome

The students will able to develop surface as well as subsurface drainage network in the agriculture field, install and laying of the drainage pipe with fitting of all accessories at their place and derive equation for different flow in drainage system and their approaches.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Waterlogging, causes of waterlogging, salt built up in waterlogged soil, solute transport in salt affected soil. Recent salt affected areas in different states and country as whole	2
2.	Technology and approach for reclamation of salt affect waterlogged areas	2

3.	Drainage requirement and crop growth under salt affected waterlogged soil. Drainage water/ brackish water quality and it's criteria for use in agriculture	2
4.	Concept of critical water table depth for waterlogged soil and crop growth	1
5.	Drainage investigations and drainage characteristics of various soils.	2
6.	Methods of drainage system: surface, sub surface, well drainage and bio-drainage and drainage coefficient	1
7.	Theories and applications of surface and sub surface drainage	3
8.	Planning, design and installation of surface and subsurface drainage systems for waterlogged and saline soils	3
9.	Theories of vertical and horizontal subsurface drainage systems	2
10.	Theory, design and application of multiple well point system	1
11.	Drainage materials. Design of filter and envelop for drainage system with different materials	2
12.	Steady state drainage equations for layered and non layer soils	2
13.	Unsteady state drainage equations for layered and non layer soils	3
14.	Principle and application, Hooghoudt and Khirkham equation	3
15.	Principles and application of Ernst, Glover Dumm, Karigenth off–van-de-law eaquation	2
16.	Drainage for salinity control, salt balance equation, leaching requirement and management practices under drained conditions, Disposal of drainage effluents	3
17.	Case study: Integrated planning, design and installation of drainage system for reclamation of salt affected waterlogged areas	2
	Total	**36**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Delineation of waterlogged areas through isobar, isobath and topographic maps	3
2.	Measurement of in-situ hydraulic conductivity	1
3.	Estimation of drainage coefficient from rainfall data	2
4.	Determination of leaching requirements for reclamation of salt affected land	2
5.	Design of surface drainage systems	2
6.	Design of subsurface drainage systems	2
7.	Design of filter and envelop materials	2
8.	Visit to drainage installation site/Institute	2
	Total	**16**

X. Suggested Reading

- Bhattacharaya AK and Michael AM. 2003. Land Drainage. Vikas Publ.
- Clande Ayres and Daniel Scoates AE. 1989. Level Drainage and Reclamation. Mc.Graw Hill.
- Luthin JN. 1978. Drainage Engineering. Wiley Eastern.
- Ritzema HP (Ed.) 1994. Drainage Principles and Applications. ILRI
- Roe CE. 1966. Engineering for Agricultural Drainage. McGraw Hill.
- Schilfgaarde Jan Van (Editor). 1974. Drainage for Agriculture. Monograph No. 17. American Society of Agronomy Madison, Wisconsin, USA.

I. Course Title : Design of Drip and Sprinkler Irrigation Systems

II. Course Code : IDE 505

III. Credit Hours : 3(2+1)

IV. Aim of the course

To provide exposure of new cutting-edge technologies to the students in design of drip and sprinkler irrigation systems including selection of pipe and fertigation techniques.

V. Theory

Unit I

Suitability of sprinkler and drip irrigation systems under Indian conditions. Basic hydraulics of sprinkler and micro irrigation system.

Unit II

Pipe flow analysis. Friction losses and pressure variation. Flow in nozzles and emitters.

Unit III

Design and evaluation of sprinkler and micro irrigation systems in relation to source, soil, climate and topographical conditions.

Unit IV

Selection of pipe size, pumps and power units. Layout, distribution, efficiency and economics.

Unit V

Fertigation through sprinkler and micro irrigation systems. Fertigation techniques involved in drip and sprinkler irrigation system.

VI. Practical

Design of drip and sprinkler irrigation system. Calculation of total head. Determination of uniformity of sprinkler discharge at field. Numerical on hydraulics of dripper. Calculation of different types of efficiencies of installed drip system. Calculation of cost benefits of drip and sprinkler irrigation system.

VII. Learning outcome

Students will understand design aspects of various drip and sprinkler irrigation systems including friction losses and flow variations. They may also expose to various fertigation techniques involved in the system.

VIII. Lecture Schedule

S.No.	Topic	No. of lectures
1	Plant-soil-atmosphere relationships	3
2	Evapotranspiration, methods for estimation of evapotranspiration, Irrigation water requirements, Irrigation principles, Numerical Problems	2
3	Drip irrigation, adaptability, limitations, components and classification of systems	2
4	Pipe flow analysis, types of friction losses in main, sub-main and lateral, pressure variation in drip irrigation system and their calculations	2

5	Design of drip irrigation system based on source of irrigation, soil, climate and topographical conditions and hydraulics of drip components with numerical problems	3
6	Selection of pipe, pump and power unit	2
7	Fertigation: advantages, limitations, methods, fertilizers solubility and their compatibility, precautions, frequency, duration and injection rate, Emitter clogging and prevention	2
8	Performance evaluation of drip irrigation system	1
9	Sprinkler irrigation, adaptability, limitations, components and classification of systems	2
10	Pipe flow analysis, types of friction losses, pressure variation in sprinkler irrigation system and their calculations	2
11	Flow in nozzles, drop size distribution, spray evaporation	1
12	Hydraulic and engineering design of sprinkler irrigation system on source of irrigation, soil, climate and topographical conditions, numerical problems	3
13	Fertigation techniques in sprinkler irrigation	1
14	Selection of pipe, pump and power unit	2
15	Performance evaluation of sprinkler irrigation system	1
16	Irrigation scheduling techniques and automation in drip and sprinkler irrigation system	2
17	Benefit cost ratio of drip and sprinkler irrigation system	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of different components of drip and sprinkler irrigation system	1
2.	Determination of physical properties of soil	1
3.	Design of drip irrigation system for orchards	1
4.	Design of micro-irrigation system for row crops	1
5.	Design of sprinkler irrigation system for vegetable crops	1
6.	Design of sprinkler irrigation system for field crops	1
7.	Estimation of total head in drip and sprinkler irrigation system	1
8.	Determination of filtration efficiency of different filters	1
9.	Evaluation of drip irrigation system	1
10.	Determination of uniformity of sprinkler discharge at field	1
11.	Study of hydraulics of drippers	1
12.	Estimation of fertigation rate in drip irrigation system	1
13.	Calculation of different types of efficiencies of installed drip system	1
14.	Study of Automation in micro-irrigation system	1
15.	Calculation of cost benefits of drip irrigation system	1
16.	Calculation of cost benefits of sprinkler irrigation system	1
	Total	**16**

X. Suggested Reading

- Jensen ME. (Editor). 1983. Design and Operation of Farm Irrigation Systems. ASAE, Mono graph No. 3. USA.

- James LG. 1988. Principles of Farm Irrigation System Design. John Wiley and Sons, New York, USA.
- Michael AM. 2006. Irrigation Theory and Practice. Vikas Publ. New Delhi.
- Withers Bruce and Vipond Stanley. 1974. Irrigation: Design and Practice. B.T. Batsford Ltd, London.
- Sivanappan RK. 1987. Sprinkler Irrigation. Oxford and IBH Publishing Co. New Delhi.

I. Course Title : GIS and Remote Sensing for Land and Water Resource Management

II. Course Code : IDE 507/SWCE 507

III. Credit Hours : 3(2+1)

IV. Aim of the course

To acquaint students with recent technology of RS and GIS including satellite data analysis, digital image processing and thematic mapping of land use, surface and ground water.

V. Theory

Unit I

Physics of remote sensing. Electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation. Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme.

Unit II

Satellite data analysis. Visual interpretation. Digital image processing. Image pre- processing. Image enhancement. Image classification. Data merging.

Unit III

Basic components of GIS. Map projections and co-ordinate system. Spatial data structure: Raster, vector. Spatial relationship. Topology. Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database. Common sources of error. Data quality: Macro, micro and Usage level components, Meta data. Spatial data transfer standards.

Unit IV

Thematic mapping. Measurement in GIS: Length, perimeter and areas. Query analysis. Reclassification, Buffering and Neighbourhood functions. Map overlay: Vector and raster overlay. Interpolation and network analysis. Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS.

Unit V

Spatial data sources. 4M GIS approach water resources system. Thematic maps. Rainfall runoff modelling, groundwater modelling and water quality modelling. Flood inundation mapping and modelling. Drought monitoring. Cropping pattern change analysis. Performance evaluation of irrigation commands. Site selection for artificial recharge. Reservoir sedimentation.

VI. Practical

Familiarization with the remote sensing instruments and satellite imagery. Aerial Photograph and scale determination with stereoscope. Interpretation of satellite imagery and aerial photograph. Determination of Parallaxes in images. Introduction to digital image processing software and GIS software and their working principles. Generation of digital elevation model (DEM) for land and water resource management. Case studies on mapping, monitoring and management of natural resources using remote sensing and GIS.

VII. Learning outcome

The student will be able to use satellite remote sensing to perform image analysis and classification for developing thematic maps and also able to integrate satellite data with GIS to undertake recourse mapping and lanning studies.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction and brief history of RS and GIS, applications of RS and GIS	1
2.	Physics of remote sensing. Electromagnetic radiation (EMR), interaction of EMR with atmosphere, earth surface, soil, water and vegetation.	1
3.	Remote sensing platforms: Monitoring atmosphere, land and water resources: LANDSAT, SPOT, ERS, IKONOS and others. Indian Space Programme	2
4.	Satellite data analysis. Visual interpretation.	1
5.	Digital image processing- Image pre-processing, Image enhancement, Image classification, data merging.	3
6.	Basic components of GIS- Map projections and co-ordinate system.	2
7.	Spatial data sources,Thematic maps.	1
7.	Spatial data structure: Raster, vector data, Spatial relationship-Topology	1
8.	Geodatabase models: Hierarchical, network, relational, object-oriented models. Integrated GIS database	3
9.	Data quality, Common sources of error, Macro, micro and Usage level components, Meta data and Spatial data transfer standards	2
10.	Measurement in GIS- Length, perimeter and areas.	1
10.	Query analysis. Reclassification, Buffering and Neighbourhood functions.	1
11.	Map overlay: Vector and raster overlay	1
12.	Interpolation and network analysis	1
13.	Digital elevation modelling. Analytical Hierarchy Process. Object oriented GIS, AM/FM/GIS and Web Based GIS.	3
14.	GIS approach to Rainfall runoff modelling, Flood inundation mapping and modelling.	2
15.	GIS approach to Groundwater modelling and water quality modelling,	2
16.	Site selection for artificial recharge. Reservoir sedimentation	1
17.	Drought monitoring	1
18.	Performance evaluation of irrigation commands	1
19.	Cropping pattern change analysis	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Familiarization with the remote sensing instruments and satellite imagery	1
2.	Methods of establishing ground truth survey and Comparison between ground truth and remotely sensed data	2
3.	Aerial Photograph and scale determination with stereoscope	1
4.	Interpretation of satellite imagery and aerial photograph	1
5.	Determination of Parallaxes in images	1
6.	Demonstration on GPS; Provision of Ground Control by GPS in different mode	1
7.	Introduction to digital image processing software	1
8.	Introduction to GIS software	1
9.	Data input; Data editing and Topology creation -Digitization of point, line and polygon features	
10.	SRTM and CARTO DEM download from web and Georeferencing of an image	1
11.	Delineation of Watershed, DEM generation: slope, Aspect, flow direction, Flow accumulation, Drainage, network and morphometric analysis	2
12.	LULC by supervised classification and LULC by unsupervised classification	1
13.	Application of Remote Sensing data and GIS for water quality parameters	
14.	Temporal satellite data analysis for vegetation condition, crop water requirement calculation	1
15.	Erosion mapping using aerial and satellite Data	1
	Total	**17**

X. Suggested Reading

- Charles Elach and Jakob van Zyl. 2006. Introduction to the Physics and Techniques of Remote Sensing. John Wiley & Sons publications.
- Ian Heywood Sarah, Cornelius and Steve Carver. 2002. An Introduction to Geographical Infor mation Systems. Pearson Education. New Delhi.
- James B Campbell and Randolph H Wynne. 2011. Introduction to Remote Sensing. The Guilford Press.
- Lillesand TM and Kiefer RW. 2008. Remote Sensing and Image Interpretation. John Wiely and Sons.
- Paul Curran PJ. 1985. Principles of Remote Sensing. ELBS Publications.
- Rees WG. 2001. Physical Principles of Remote Sensing. Cambridge University Press.
- Thanappan Subash. 2011. Geographical Information System. Lambert Academic Publishing.

I. Course Title : Waste Water Management and Utilization in Agriculture

II. Course Code : IDE 508

III. Credit Hours : 3(2+1)

IV. Aim of the course

To acquaint students about status of waste water and water quality requirements, standards both for domestic and irrigation purposes and also to provide in depth knowledge of waste water treatment methods and utilization in agriculture.

V. Theory

Unit I

Status of wastewater in India. Sources of contamination and characterization of urban and rural wastewater for irrigation. Water quality: Physical, chemical and biological parameters of wastewater.

Unit II

Water quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards and guidelines for their restricted and unrestricted uses. Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization.

Unit III

Control measures for preventing soil and other surface/groundwater source contamination. Different types of wastewater, pollutants and contaminants. Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.

Unit IV

Wastewater treatment methods: Physical, chemical and biological. General water treatments: Wastewater recycling, constructed wetlands, reed bed system. Carbon foot prints of wastewater reuse. Environmental standards.

Unit V

Regulation and environmental impact assessment (EIA): Environmental standards- CPCB Norms for discharging industrial effluents to public sewers. Stages of EIA- Monitoring and Auditing. Environmental clearance procedure in India.

VI. Practical

Measurement of water quality indices in the lab. Field demonstration of impact of waste water on eco-system and human health. Waste water treatment methods and effect of waste water in contamination of ground water. Visit of waste water treatment plant near by area.

VII. Learning outcome

The students will be able to understand sources and treatment methods of waste water quality with standard norms of water quality for domestic and irrigation purposes and also be exposed to waste water recycling and environmental standards.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Status of wastewater in India, Sources of contamination and characterization of urban and rural wastewater for irrigation	2
2.	Water quality: Physical, chemical and biological parameters of wastewater	2
3.	Wastewater quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards both national and global and guidelines for their restricted and unrestricted uses.	2
4.	Different types of wastewater, pollutants and contaminants.	1
5.	Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.	2

6.	Key drivers of wastewater use in agriculture and existing approaches for regulating wastewater reuse in agriculture	2
7.	Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization and practices used for irrigation	3
8.	Health Risks Associated with the Use of Wastewater for Irrigation	1
9.	Wastewater treatment methods: Physical, chemical and biological.	3
10.	Choice of (Cost-Effective) Wastewater Treatment Systems for Irrigation	2
11.	General water treatments: Wastewater recycling, constructed wetlands, reed bed system.	2
12.	Carbon foot prints of wastewater reuse. Environmental standards.	2
13.	Management of health and environmental risks of wastewater irrigation	1
14.	Regulation and environmental impact assessment (EIA): Environmental standards-CPCB Norms for discharging industrial effluents to public sewers. Valuation of environmental impacts.	3
15.	Impact on groundwater resources and soil health, EIA process, Stages of EIA-monitoring and auditing. Environmental clearance procedure in India	3
16.	Economics of wastewater irrigation	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study on physical, chemical and biological parameters of wastewater	1
2.	Determination of EC and pH of wastewater	1
3.	Determination of BOD of wastewater	1
4.	Determination of COD of wastewater	1
5.	Determination of TSS and TDS of wastewater	1
6.	Determination RSC of wastewater	1
7.	Determination of e-coli in the wastewater	1
8.	On field demonstration of wastewater use for the irrigation	1
9.	Determination of nutrient (N, P and K) concentration in wastewater	2
10.	Field demonstration of impact of waste water on eco-system and human health.	1
11.	Study on various wastewater treatment methods	2
12.	Study on effect of wastewater on contamination of ground water	1
13.	Visit of village pond treatment nearby area	1
14.	Visit of sewerage treatment plant nearby area	1
	Total	**16**

X. Suggested Reading

- Charis Michel Galanakis. Sustainable Water and Wastewater Processing. Elsevier Publication, Amsterdam.
- Sean X Liu. 2014. Food and Agricultural Wastewater Utilization and Treatment. Wileu Blackwell New York.
- Shirish H, Sonawane Y, Pydi Setty T, Bala Narsaiah and S Srinu Naik. 2017. Innovative Technologies for the Treatment of Industrial Wastewater: A Sustainable Approach. CRC Press.
- Stuetz Richard. Principles of Water and Wastewater Treatment Processes (Water and Wastewa ter Process Technologies). IWA Publishing.
- Syed R Qasim and Guang Zhu. 2018. Wastewater Treatment and Reuse: Theory and Design Examples. CRC Press.

I. Course Title : Irrigation Economics Planning and Management

II. Course Code : IDE 514

III. Credit Hours : 2(2+0)

IV. Aim of the course

To impart knowledge of various public and government policy on regulation and allocation of irrigation water, cost and benefit analysis including project evaluation, decision making process and risk analysis.

V. Theory

Unit I

Economic analysis. Problems in project selection. Methods and approaches to water pricing. Criteria for investment and pricing in irrigation projects. Social benefits, problems and causes of under-utilization. Mathematics of economic analysis. Cost allocation, separable and non-separable costs. Discounting factors and techniques. Determination of benefits, cost and benefit analysis. Project evaluation. Limitations of benefit-cost analysis. Dynamics of project analysis.

Unit II

Role of financial analysis. Distinctions from economic analysis. Financial feasibility and analysis. Impact of public policies on regulation and allocation of irrigation water. Relative economic efficiency of alternative irrigation water management models. Irrigation system improvement by simulation and optimization to enhance irrigation water use efficiency.

Unit III

Indian agriculture, main problems, population, government policies, systems, organizing agriculture production. Farm Management: Definition, importance, scope, relation with other sciences and its characteristics.

Unit IV

Socio-economic survey. Importance of such survey in planning, implementation and evaluation of project performance. Planning of socio-economic survey, types of data sets to be collected, preparing the questionnaires form, schedules sampling, editing and scrutinizing of secondary data, classification and analysis of data.

Unit V

Role of farm management principles in decision making for irrigated agriculture. Decision making process, assessing risk and uncertainty in planning.

VI. Learning outcome

The students will be able to estimate the cost benefit analysis, pricing and investment criteria on irrigation project evaluation and finding their problems.The students will also expose to conduct socio-economic survey and analyse secondary data.

VII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Economic analysis, problems in project selection	1
2.	Methods and approaches to water pricing	1
3.	Criteria for investment and pricing in irrigation projects	1
4.	Social benefits, problems and causes of under-utilization	1
5.	Mathematics of economic analysis	1
6.	Cost allocation, separable and non-separable costs	1
7.	Discounting factors and techniques	1
8.	Determination of benefits and limitations of cost-benefit analysis	1
9.	Project evaluation	1
10.	Dynamics of project analysis	1
11.	Role of financial analysis	1
12.	Distinctions from economic analysis	1
13.	Financial feasibility and analysis	1
14.	Impact of public policies on regulation and allocation of irrigation water	1
15.	Relative economic efficiency of alternative irrigation water management models	2
16.	Irrigation system improvement by simulation and optimization to enhance irrigation water use efficiency	2
17.	Indian agriculture, main problems, population, government policies, systems, organizing agriculture production	2
18.	Farm Management: Definition, importance, scope, relation with other sciences and its characteristics	2
19.	Socio-economic survey: Importance of survey in planning, implementation and evaluation of project performance	2
20.	Planning of socio-economic survey, types of data sets to be collected, preparing the questionnaires form, schedules sampling, editing and scrutinizing of secondary data	2.
21.	Classification and analysis of data	1
22.	Role of farm management principles in decision making for irrigated agriculture	2
23.	Decision making process	1
24.	Assessing risk and uncertainty in planning	2
	Total	**32**

VIII. Suggested Reading

- Heady, Early Orel, Hexem R and Roger W. 1978. Water Production Functions for Irrigated Agriculture.
- James Douglas and Lee Rober R. 1995. Economics of Water Resource Planning. Tata Mcgraw-Hill Publication Company Ltd, Bombay, New Delhi.
- Joshi SS and TR Kapoor. 2001. Fundamentals of Farm Business Management. Kalyani Publishers, Ludhiana.
- Management of Water Project-Decision Making and Investment Appraisal. Oxford Publication Co.
- Sharma VK. 1985. Water Resource Planning and Management. Himalaya Publication House, New Delhi.

I. **Course Title : Sensing and Automation in Irrigation Systems**

II. **Course Code : IDE 515**

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

IV. **Aim of the course**

To acquaint students about the concept of sensing and automation in irrigation system, wireless sensor network and digital signal processor. To provide knowledge of surface irrigation automation.

V. **Theory**

Unit I

Sensing and sensors. Sensor classifications. Wireless sensor networks. History of wireless sensor networks (WSN). Communication in a WSN. Important design constraints of a WSN like Energy, self management, wireless networking, decentralized management, design constraints, security etc.

Unit II

Node architecture. Sensing subsystem. Analog-to-Digital converter. The processor subsystem, architectural overview, microcontroller, digital signal processor, application-specific integrated circuit, field programmable gate array (FPGA).

Unit III

Communication interfaces, serial peripheral interface, inter-integrated circuit, the IMote node architecture, The XYZ node architecture, the Hogthrob node architecture.

Unit -IV

Applications in surface irrigation automation, automation based on volume, time, fertigation scheduling, water logging, salinity, oxygen diffusion systems, etc.

VI. **Learning outcome**

The students will be able to understand concept of automation in irrigation system which is quite important to enhance water use efficiency and also able to understand Node architecture and other routing protocols.

VII. **Lecture Schedule**

S.No.	Topics	No. of Lectures
1.	Sensing and sensors	2
2.	Sensor classifications	2
3.	History of wireless sensor networks (WSN) and Wireless sensor networks	3
4.	Communication in a WSN	1
5.	Important design constraints of a WSN like Energy, self-management, wireless networking, decentralized management, design constraints, security etc	3
6.	Node architecture	1
7.	Sensing subsystem	1
8.	Analog-to-Digital converter	2
9.	The processor subsystem	1
10.	Architectural overview	1

11.	Microcontroller	2
12.	Digital signal processor	2
13.	Application-specific integrated circuit	2
14.	Fieldprogrammable gate array (FPGA)	2
15.	Communication interfaces	2
16.	Serial peripheral interface	3
17.	Inter-integrated circuit	2
18.	The IMote node architecture	2
19.	The XYZ node architecture	2
20.	The Hogthrob node architecture	2
21.	Applications in surface irrigation automation	3
22.	Automation based on volume, time, fertigation scheduling,water logging, salinity, oxygen diffusion systems, etc	4
	Total	**45**

VIII. Suggested Reading

- Cauligi S Raghavendra, Krishna M Sivalingam and Taieb Znati. Wireless Sensor Networks. Springer.
- Edgar H, Callaway Jr. and Edgar H Callaway. Wireless Sensor Networks: Architectures and Protocols.
- Holger Karl and Andreas Willig. Protocols and Architectures for Wireless Sensor Networks. John Wiley & Sons.
- Waltenegus Dargie and Christian Poellabauer. Fundamentals of Wireless Sensor Networks: Theory and Practice. A John Wiley and Sons, Ltd, Publication.

Course Title with Credit Load

Renewable Energy Engineering

Course Code	Course Title	Credit Hours
REE 501	Renewable Energy Technologies	3(2+1)
REE 502	Solar Thermal Energy Conversion Technologies	3(2+1)
REE 503	Biomass Energy Conversion Technologies	3(2+1)
REE 504	Energy Auditing, Conservation and Management	3(2+1)
REE 507	Renewable Energy Policy, Planning and Economics	3(3+0)

Course Contents
Renewable Energy Engineering

I. Course Title : Renewable Energy Technologies

II. Course Code : REE 501

III. Credit Hours : 3(2+1)

IV. Aim of the course

To provide knowledge, understanding and application oriented skills on renewable energy sources and relevant technologies towards their effective utilization for meeting energy demand.

V. Theory

Unit I

Solar Energy: Heat transfer, estimation and physical conversion, Instruments for measurement. Energy collection and analysis: FPC, ETC, concentrating collectors. Solar energy application: Direct and indirect. Solar photovoltaic technology: Conversion, Systems components, integrations and applications.

Unit II

Energy from biomass and wastes: Production, distribution, characterization, treatments, recycling. Biomass conversion technologies: Thermo-chemical, bio- chemical and agro-chemical technology. Raw materials, process parameters, end products and utilization.

Unit III

Wind energy: Resource estimation, technologies, performance curves, power and torque characteristics. Airfoils and rotors: Wind mill parameters, wind farms design and considerations.

Unit IV

Alternate Energy Technologies: Ocean Thermal Energy Conversion, Geothermal, Tidal, Hydro. Energy conversion systems: Resources, systems integrations and analysis, applications. Energy storage: Types, materials, characteristics and application.

VI. Practical

Analysis of solar collectors.Solar Photovoltaic cell characteristics, analysis of SPV systems.Characterization of biomass. Design and benefit analysis of energy systems. Design and efficiency testing of wind energy conversion devices.

VII. Learning outcome

The students is acquainted the skill to understand technical aspects and principles of renewable energy characteristics of the resource base (solar radiation, wind energy, bio energy, etc.) In a further steps an economic analysis of supply technologies.

VIII. Lecture Schedule

S.No.	Topics	No. of Lectures
1.	Solar energy: introduction. Solar radiations measuring Instruments	1
2.	Passive Flat plate solar collectors, types. Passive solar water heaters. Performance of solar water heater. Effect of various parameters on performance	2
3.	Solar passive concentrators: Brief introduction to main types of solar concentrators, solar cookers	1
4.	Solar passive crop dryers: Description of various types of solar crop dryers, Applications of solar crop dryers	2
5.	Solar photovoltaic technology: Conversion, Systems components, integrations and applications	2
6.	Biomass Production, distribution, characterization, treatments, recycling.	1
7.	Review of gasifiers basics; Selection criteria for type and capacity of gasifier; Performance parameters for gasifiers e.g. SGR, turn down ratio etc;	1
8.	Basic design of small scale Imbert type downdraft gasifier (without use of Tables) and Basic features of throatless and inverted downdraft gasifiers (No designing)	1
9.	Baling for densification of biomass and briquetting machines for densification of biomass	1
10.	Bio-chemical and agro-chemical technologies for biomass conversion	2
11.	Raw materials, process parameters, end products and utilization for bio-chemical and agro-chemical technologies	2
12.	Resource estimation of wind energy, technologies and performance curves	2
13.	Power and torque characteristics	2
\14.	Wind mill parameters	2
15.	Wind farms design and considerations	2
16.	Ocean Thermal Energy Conversion	2
17.	Geothermal, Tidal and Hydro Energy conversion systems	2
18.	Energy storage: Types, materials, characteristics and application	4
	Total	**32**

List of Practicals

S.No.	Topics	No. of Practicals
1.	Sensing and sensors	2
1.	Analysis of solar collectors	3
2.	Solar Photovoltaic cell characteristics, analysis of SPV systems	3
3.	Characterization of biomass	4
4.	Design and benefit analysis of energy systems	3
5.	Design and efficiency testing of wind energy conversion devices	3
	Total	**16**

X. Suggested Reading

- Culp AW. 1991. *Principles of Energy Conversion.* McGraw-Hill Pub. Co Inc., New York.
- Duffie JA and Beckman WA. 1991. *Solar Engineering of Thermal Processes*. John Wiley, New York.

- Garg HP and Prakash J. 1976. *Solar Energy, Fundamentals and Applications*. Tata McGraw-Hill Pub. Co. Inc., New Delhi.
- Odum HT and Odum EC. 1976. *Energy Basis for Man and Nature*. McGraw-Hill Pub. Co. Inc., New York.
- Sukhatme SP. 1997. *Solar Energy, Principles of Thermal Collection and Storage*. Tata McGraw-Hill. Pub. Co. Ltd, New Delhi.
- Twidell JW and Weir AD. 1986. *Renewable Energy Sources*. E & FN Spon Ltd., London.

I. Course Title : C

I. Course Title : Solar Thermal Energy Conversion Technologies

II. Course Code : REE 502

III. Credit Hours : 3(2+1)

IV. Aim of the course

To provide in-depth knowledge, understanding and application oriented skills on solar thermal conversion technologies and their effective utilization for meeting energy demand.

V. Theory

Unit I

Characteristics of solar radiation: Attenuation, absorption, scattering and air mass. Solar earth geometry.

Unit II

Solar flux and weather data. Solar radiation data and estimation: Radiation estimation models and applications. Heat and mass transfer in solar energy utilization: Gray surface, sky radiation, radiation heat transfer coefficient, reflectivity, transitivity, transmittance absorption product. Selective surfaces and materials.

Unit III

Solar thermal energy collectors (track and untrack): Heat capacity effect, time constant measurement, design and efficiency calculations, F chart method utility.

Unit IV

Techno-economic feasibility of solar thermal energy applications: Cooking, air heating for drying, steam generation, space heating and cooling, refrigeration, architecture, absorption cooling, thermal power generation.

VI. Practical

Solar radiation measurement, estimation model applications, design of collectors, study of materials used in solar system. Energy balance and efficiency calculation of collectors.

VII. Learning outcome

The student is able to understand the detail knowledge about working and design of various solar thermal devices able to design different solar thermal devices.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Introduction to characteristics of solar radiation and Solar earth geometry	2
2.	Solar flux and weather data measurement and interpretation	2
3.	Estimation of Solar radiation data using models and estimation	3
4.	Heat and mass transfer in solar energy utilization	2
5.	Gray surface, sky radiation, radiation heat transfer coefficient	2
6.	Reflectivity, Transitivity, Transmittance Absorption	2
7.	Selective surfaces and materials as solar energy collectors	2
8.	Heat capacity effect, time constant measurement of solar energy	2
9.	Design and efficiency calculations of Solar thermal energy collectors	4
10.	F chart method utility for Designing Solar Thermal Water Heating Systems	2
11.	Techno-economic feasibility of solar thermal energy in cooking, drying of food products, space heating and cooling.	4
12.	Economic feasibility of solar thermal energy in refrigeration, architecture, absorption cooling, thermal power generation.	4
	Total	**30**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Measurement of Solar radiation	1
2.	Estimation of solar energy by model applications	2
3.	Design of solar energy collectors	2
4.	Study of materials used in solar system	1
5.	Energy balance in solar energy collectors	2
6.	Efficiency calculation of collectors	2
	Total	**10**

X. Suggested Reading

- Bansal NK, Kleeman MK and Meliss M. 1990. *Renewable Energy Sources and Conversion Technologies*.Tata McGraw-Hill Pub. Co. Ltd, Delhi.
- Duffie JA and Beckman WA. 2006. *Solar Thermal Engineering Process*. John Wiley & Sons, New Jersey.
- Hsien JS. 2014. *Solar Energy*. Prentice Hall Inc., New Jersey.
- Garg HP. 1990. *Advances in Solar Energy Technology*. Springer Publishing Company, Dordrecht, Netherland.
- Kalogirou SA. 2013. *Solar Energy Engineering.* Academic Press, Cambridge, Massachusetts.
- Kishore VVN. 2008. *Renewable Energy Engineering and Technology–A Knowledge Com pendium*. TERI Press, New Delhi, India.
- Pai BR and Ramaprasad MS. 1991. *Power Generation through Renewable Sources of Energy.* Tata McGraw-Hill Pub. Co., New Delhi.
- Sukhatme SP and Nayak J. 2008. S*olar Energy: Principles of Thermal Collection and Storage*. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

I. Course Title : Biomass Energy Conversion Technologies

II. Course Code : REE 503

III. Credit Hours : 3(2+1)

IV. Aim of the course

To understand the bio-conversion technologies and fuels system, types of biomass derived fuels and energy, thermo-chemical conversion of biomass to heat and power, value adding of agro-residues.

V. Theory

Unit I

Biomass characterization: Types and resources, sustainability issues, assessment tools and methodologies, biomass fuel characterization, Biomass supply chain concept. Direct use of biomass: Size reduction, baling, pelletization, briquetting technologies.

Unit II

Biochemical conversion of biomass: Feedstock, process design, operation, optimized process parameters and utilization for biogas and bioethanol production.

Unit III

Biomass combustion: Stoichiometric air requirement, chemistry of combustion, design of combustion system, combustion zones, flame structure, stability, emissions. Co-firing of biomass.

Unit IV

Thermo-chemical conversion of biomass: Feedstock, chemistry, reactor design, operation, optimized process parameters and utilization for gasification, carbonization, torrefaction and pyrolysis.

Unit V

Cogeneration technologies: Cycles, topping, bottoming, selection, problems, applications. Waste heat recovery: Estimation, systems, design and application.

VI. Practical

Biomass characterization.Design of bioreactors.Study of techno-economical feasibility of biochemical conversion process.Performance evaluation of combustion gadgets, gasifiers and pyrolytic converters.Design of waste heat recovery system.

VII. Learning outcome

The students is enable to extract the energy from biomass and acquainted the skill to know how to choose the suitable biomass fuels for different industrial applications with design and economics of the system.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Biomass characterization: Types and resources, sustainability issues, assessment tools and methodologies, biomass fuel characterization, Biomass supply chain concept.	3
2.	Direct use of biomass	1
3.	Size reduction, baling, pelletization, briquetting technologies.	2

4.	Biochemical conversion of biomass	1
5.	Feedstock, process design, operation, optimized process parameters.	2
6.	Utilization for biogas and bioethanol production.	1
7.	Biomass combustion	1
8.	Stoichiometric air requirement, chemistry of combustion.	3
9.	Design of combustion system.	2
10.	Combustion zones, flame structure, stability, emissions.	2
11.	Co-firing of biomass.	1
12.	Thermo-chemical conversion of biomass: Feedstock, chemistry.	2
13.	Reactor design.	1
14.	Operation, optimized process parameters and utilization for gasification, carbonization, torre action and pyrolysis.	2
15.	Cogeneration technologies: Cycles, topping, bottoming, selection.	2
16.	Cogeneration Problems and applications.	2
17.	Waste heat recovery	2
18.	Estimation, systems, design and application.	2
	Total	**32**

IX. List of Practicals

S.No.	Topics	No. of Practicals
1.	Characterization of biomass	2
2.	Design of bio-reactors	1
3.	Determination of techno-economical feasibility of bio-chemical conversion process.	2
4.	Performance evaluation of combustion gadgets	1
5.	Performance evaluation of gasifiers	1
6.	Performance evaluation of pyrolytic converters	1
7.	Design of waste heat recovery system	2
	Total	**10**

X. Suggested Reading

- Chakravorty A. 1985. *Biogas Technology & other Alternative Technologies*. Oxford & IBH Publication Ltd, Delhi.
- Chaturvedi P. 1995. *Bio-Energy Resources: Planning, Production and Utilization*. Con cept Pub. Co., New Delhi.
- Goswami DY. 1986. *Alternative Energy in Agriculture*.Vol. II (Ed), CRC, Press Inc., Florida, USA.
- Stout BA. 1984. *Biomass Energy Profiles*. FAO Agril. Services Bulletin No.54., Elsevier Science Publishers Ltd, England.
- Twidell JW and Weir AD. 2006. *Renewable Energy Sources*. E & F N Spon Ltd, New York.
- Vimal OP. 1984. *Energy from Biomass*.Agrcole Publishing Academy, New Delhi.

I. Course Title : Energy Auditing, Conservation and Management

II. Course Code : REE 504

III. Credit Hours : 3(2+1)

IV. Aim of the course

To acquaint and equip about the sources of energy, conservation of energy and its management. Study of energy efficiency, energy planning, forecasting and energy economics.

V. Theory

Unit I

Energy conservation: Concepts, energy classification, equivalents, scenario, energy pricing, importance. Energy conservation act.

Unit II

Energy auditing and economics: Energy management, energy audit strategy, types. Energy performance: Bench marking, fuel substitutions, energy audit instruments, material and energy balance. Energy conversion: Energy index, cost index. Financial management.

Unit III

Thermal energy audit: Performance evaluation, energy conservation opportunities in boilers, steam system and furnaces, insulation, refractory's and other thermal utilities.

Unit IV

Electrical Energy audit: Electrical systems, electricity billing, load management, power factor. Performance evaluation and energy conservation opportunities in motors, compressed air system, HVAC and refrigeration system, fans and blowers, pumps and lighting system.

Unit V

Energy auditing and reporting in industries, Replacement of renewable energy technology option, case study in agro-industries.

VI. Practical

Problems on energy index, cost index. Problems on material balance and energy balance. Financial management.Energy audit and conservation opportunities in thermal and electrical utilities. Case studies on energy audit and conservation.

VII. Learning outcome

Able to understand the concept of energy auditing, conservation and management. The in-depth knowledge about the quantification, conservation opportunity and retrofitting of energy efficient system integration is expected from the course.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Energy conservation: Introduction, Concepts, Scenario	2
2.	Classification of Energy	1
3.	Energy equivalents, energy pricing, importance.	2

4.	Energy conservation act.	2
5.	Introduction to energy management, energy audit strategy and types.	2
6.	Energy performance: Bench marking, fuel substitutions.	1
7.	Energy audit instruments, material and energy balance.	2
8.	Energy conversion: Energy index, cost index. Financial management.	2
9.	Performance evaluation and energy conservation opportunities in boilers.	1
10.	Insulation, refractory's and other thermal utilities.	2
1.	Performance evaluation and energy conservation opportunities in steam system and furnaces.	2
12.	Electrical Energy audit: Electrical systems, electricity billing, load management, power factor.	2
13.	Performance evaluation and energy conservation opportunities in motors, compressed air system.	2
14.	Performance evaluation and energy conservation opportunities in HVAC and refrigeration system.	2
15.	Performance evaluation and energy conservation opportunities in fans and blowers, pumps and lighting system.	2
16.	Energy auditing and reporting in industries.	1
17.	Replacement of renewable energy technology option.	2
18.	Case study in agro-industries.	2
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Problems on energy index.	2
2.	Problems on cost index.	2
3.	Problems on material balance.	2
4.	Problems on energy balance.	2
5.	Financial management.	2
6.	Energy audit and conservation opportunities in thermal utilities.	2
7.	Energy audit and conservation opportunities in electrical utilities.	2
8.	Case studies on energy audit and conservation.	2
	Total	**16**

X. Suggested Reading

- *Energy Management*, *Bi-monthly Journal* National Productivity Council, New Delhi.
- Guide Books for *National Certification Examination for Energy Managers and Energy Auditors,* Book 1–4, 2005 Bureau Energy Efficiency, New Delhi.
- Murgai MP and Chandra R. 1990. *Progress in Energy Auditing and Conservation, Boiler Operations.* Wiley Eastern Ltd, New Delhi.
- Murphy WR and McKay G. 1982. *Energy Management*. Butterworth & Co., Publishers Ltd., London.
- Porter R and Roberts T. 1985. *Energy Saving by Waste recycling*. Elsevier applied science publishers, New York, USA.

- Smith CB. 1981. *Energy Management Principles, Applications, Benefits and Savings*. Pergamon Press Inc., Oxford, England.
- Victor B. 1983. *Ottaviano, Energy Management*. An OTIS Publication, Ottaviano Technical Service Inc., Melville, New York.

I. Course Title : Renewable Energy Policy, Planning and Economics

II. Course Code : REE 507

III. Credit Hours : 3(3+0)

IV. Aim of the course

To provide the in-depth knowledge about the current energy policy and planning, environmental economics, policy and ecology.

V. Theory

Unit I

Introduction to policy parameters, regulatory bodies.Introduction to overall policy environment on energy sector, policy formulation parameters. Entities: Consumers and their tariffs, generator, DISCOM, Regulators: CERC and SERC, Statutory bodies. Typical issues of Indian power sector.

Unit II

Indian energy Policy: Introduction, Electricity Act, National Policy on Tariff, Climate Change, RE, Solar Missions, Wind Power and Regulatory Commissions. Concept of Grid Code, Green Corridor, Solar and Hybrid Parks. Electricity Trading: Open Access, RPO Distributed Generation Regional Grid Region. International Energy Policies and Treaties.

Unit III

Policy and planning: Energy, environment interaction, clean development mechanism, financing of energy systems, software for energy planning, socio- economical approach. Project management in energy: Cost economics-sensitivity and risk analysis.

Unit IV

Energy economics: economic evaluation of renewable energy systems, life cycle costing, components of energy investment and risk and uncertainties in energy investment.

VI. Learning outcome

A student is be able to develop an interdisciplinary knowledge base that will enable them to understand and solve contemporary energy policy, planning and environmental problems.

VII. Lecture Schedule

S.No.	Topic	No. of Practicals
1.	Introduction to policy parameters and regulatory bodies in Energy	2
2.	Introduction to overall policy environment on energy sector, policy formulation parameters	3
3.	Entities: Consumers and their tariffs	2
4.	Generator, DISCOM, Regulators: CERC and SERC, Statutory bodies.	3

5.	Typical issues of Indian power sector.	2
6.	Introduction to Indian energy Policy and Electricity Act	3
7.	National Policy on Tariff	2
8.	Climate Change, RE, Solar Missions, Wind Power and Regulatory Commissions	3
9.	Concept of Grid Code, Green Corridor, Solar and Hybrid Parks.	3
10.	Clean development mechanism, financing of energy systems	3
11.	Policy and planning in Energy, environment interaction	2
12.	Electricity Trading: Open Access, RPO Distributed Generation Regional Grid Region. International Energy Policies and Treaties.	4
13.	Software for energy planning, socio-economical approach.	3
14.	Project management in energy: Cost economics-sensitivity and risk analysis.	4
15.	Energy economics: economic evaluation of renewable energy systems	3
16.	Life cycle costing, components of energy investment	3
17.	Risk and uncertainties in energy investment	3
	Total	**48**

VIII. Suggested Reading

- BEE Reference book: no.1/2/3/4.
- Bhattacharyya SC. 2011. *Energy Economics*. Springer, New York City, USA.
- Brown CE. 2002. *World Energy Resources.* Springer, New York City, USA.
- Conti J. 2016. *International Energy Outlook.* US Energy Information Administration (*EIA*), ashington.
- Culp AW. 1991. *Principles of Energy Conversion*. McGraw-Hill Int. edition, New York.
- Krithika PR and Mahajan S. 2014. *Governance of Renewable Energy in India: Issues and Challenges*. TERI, New Delhi.
- Parikh JK. 1981. *Modeling Approach to Long Term Demand and Energy Policy Impliation for India.* IIASA, Laxenburg, Austria.
- Reddy AKN, Williams RH, Goldenberg J and Johansson TB. 1987. *Energy for a Sustain able World.* Wiley-Eastern Ltd, New Delhi, India.
- TEDDY Year Book Published by Tata Energy Research Institute (TERI).

Soil and Water Conservation Engineering

Course Title with Credit Load

Course Code	Course Title	Credit Hours
SWCE 501	Advanced Soil and Water Conservation Engineering	3(2+1)
SWCE 502	Applied Watershed Hydrology	3(2+1)
SWCE 503	Soil and Water Conservation Structures	3(2+1)
SWCE 505	Watershed Management and Modeling	3(2+1)
SWCE 510	Dryland Water Management Technologies	2(2+0)

Course Contents
Soil and Water Conservation Engineering

I. Course Title : Advanced Soil and Water Conservation Engineering

II. Course Code : SWCE 501

III. Credit Hours : 3(2+1)

IV. Aim of the course

To acquaint and equip students with the advances in soil and water conservation measures, use of RS and GIS and Software's for design of soil and water conservation structures.

V. Theory

Unit I

Concept of probability in design of soil and water conservation structures. Probability and continuous frequency distribution. Fitting empirical distributions.

Unit II

Relevance of soil and water conservation in agriculture and in the river valley projects. Layout and planning of soil and water conservation measures. Software's for design of conservation structures.

Unit III

Productivity loss due to soil erosion. Water stress and water excess. Types and mechanics of soil erosion. Software's for soil loss estimation, WEAP, EPIC

Unit IV

Theories of sediment transport. Control of runoff and sediment loss. Sediment deposition process. Estimation of sediment load.

Unit V

Design of soil and water conservation structures: Check dams, gully plugs, gabion structures, earth dams, silt detention dams, farm ponds, etc., and the alternate use of the stored water for agriculture. Application of Remote Sensing and GIS in Soil and Water Conservation.

VI. Practical

Assessment of erosive status of a watershed through field measurement or analysis of morphometric properties. Estimation of erosivity index of rainfall. Determination of soil physical properties: Texture, grain size distribution, Atterberg's limits, various moisture percentages. Locating best possible sites of soil and water conservation structures on the basis of map features and erosivity status. Estimation of costs of soil and water conservation measures.

VII. Learning outcome

The students will able to plan and design soil and water conservation measures in particular watershed using RS and GIS techniques. They can estimate the sedimentation and capacity losses, design of gully control structures and earthen dams using software's.

VIII. Lecture Schedule

S.No.	Topic	No. of Practicals
1.	Concept of probability in design of soil and water conservation structures	2
2.	Probability and continuous frequency distribution	2
	Fitting empirical distributions	2
3.	Relevance of soil and water conservation in agriculture and in the river valley projects	2
4.	Layout and planning of soil and water conservation measures	2
5.	Software's for design of conservation structures	1
6.	Productivity loss due to soil erosion	1
7.	Water stress and water excess	1
8.	Types and mechanics of soil erosion	1
9.	Software's for soil loss estimation, WEAP, EPIC	3
10.	Theories of sediment transport	2
11.	Control of runoff and sediment loss	1
12.	Sediment deposition process and estimation of sediment load	2
13.	Design of soil and water conservation structures: Check dams, gully plugs, gabion structures, earth dams, silt detention dams, farm ponds, etc., and the alternate use of the stored water for agriculture	6
14.	Application of Remote Sensing and GIS in Soil and Water Conservation	3
	Total	**31**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Assessment of erosive status of a watershed through field measurement	2
2.	Morphometric analysis of a watershed	2
3.	Estimation of erosivity index of rainfall	1
4.	Determination of soil texture	1
5.	Determination of soil grain size distribution	1
6.	Determination of Atterberg's limits of soil	1
7.	Determination of various soilmoisture percentages	1
8.	Locating best possible sites of soil and water conservation structures on the basis of map features and erosivity status	2
9.	Design of Check dams, gully plugs, gabion structures, earth dams, silt detention dams and farm ponds	4
10.	Estimation of costs of soil and water conservation measures	2
	Total	**17**

X. Suggested Reading

- Garg SK. 1987. *Irrigation Engineering and Hydraulic Structures*. Khanna Publishers, New Delhi.
- Kirkby MJ and Morgan PPC (eds). 1980. *Soil Erosion*. John Wiley and Sons. New York, USA.
- Suresh R. 2016. *Soil and Water Conservation Engineering*. Standard Publishers and Distributors, Delhi.

I. Course Title : Applied Watershed Hydrology

II. Course Code : SWCE 502

III. Credit Hours : 3(2+1)

IV. Aim of the course

To provide in depth knowledge of surface and sub-surface hydrology of watershed including stream flow measurement and computer simulation of hydrological processes in small watersheds.

V. Theory

Unit I

Hydrology in water resources planning, rainfall, surface runoff and sub-surface runoff as components of hydrologic cycle. Runoff phenomena, relationship between precipitation and runoff. Stream flow measurement and analysis of data in detail.

Unit II

Synthetic unit hydrograph. Recent advances in analysis of hydrologic data and flow from small watersheds. Methods of runoff estimation from small watersheds. Use of IUH and various methods of estimation. Runoff estimation models: SCS, CN software.

Unit III

Micro climate, estimation methods of evaporation. Advances and improvements in rational approach. SCS approach criticism and improvements.

Unit IV

Hydrological hazard functions. Methods of estimation of hydrologic parameters. Data transformation.

Unit V

Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds.

VI. Practical

Delineation of watershed and study of watershed characteristics. Measurement of rainfall and runoff in a watershed and data analysis. Estimation of infiltration and runoff from a watershed. Analysis and derivation of various types of hydrographs. Flood routing. Reservoir sedimentation. Watershed model components. Visit to a watershed.

VII. Learning outcome

The students will be able to understand and analyze the process and the effect of various climatic parameters on rainfall-runoff relationship. They can also be able to develop the competency for calibration and evaluation of hydrologic models and computer simulation.

VIII. Lecture Schedule

S.No.	Topic	No. of Practicals
1.	Hydrology in water resources planning, rainfall, surface runoff and sub-surface runoff as components of hydrologic cycle	2

2.	Basics of watershed hydrology and processes, global and watershed perspectives	2
3.	Runoff phenomena, relationship between precipitation and runoff	1
4.	Synthetic unit hydrograph, Unit hydrograph and its derivation including for complex storm,	3
5.	S-hydrograph and derivation, Use of IUH and various methods of estimation.	3
6.	Runoff estimation models: SCS, CN software	3
7.	Flood routing principles	2
8.	Recent advances in analysis of hydrologic data and flow from small watersheds. Methods of runoff estimation from small watersheds.	3
9.	Micro climate, estimation methods of evaporation. Advances and improvements in rational approach. SCS approach criticism and improvements	3
10.	Process of sedimentation of reservoirs	2
11.	Hydrological hazard functions, Methods of estimation of hydrologic parameters, Data transformation,	3
12.	Hydrologic modeling approaches, component conceptualization, types of watershed hydrologic models and choice of model.	3
13.	Calibration and evaluation of hydrologic models. Computer simulation of hydrological process in small watersheds	2
	Total	**32**

VIII. List of Practicals

S.No.	Topic	No. of Practicals
1.	Delineation of watershed and study of watershed characteristics	1
2.	Measurement of rainfall and runoff in a watershed	1
3.	Analysis of hydrologic data and flow from small watersheds	1
4.	Estimation of infiltration and runoff from a watershed	1
5.	Measurement and analysis of stream flow data	1
6.	Analysis of synthetic unit hydrograph for complex storm	1
7.	Analysis of S-hydrograph for complex storm	1
8.	Use of runoff estimation models: SCS, CN software	2
9.	Study of different types of flood routing methods	2
10.	Computer simulation of hydrological process in small watersheds	1
11.	Study of reservoir sedimentation	1
12.	Study of watershed model components	1
13.	Visit to a watershed	1
	Total	**16**

IX. Suggested Reading

- Haan CT. *Hydrologic Modeling of Small Watershed*.
- Singh VP. 2010. *Rainfall-Runoff Modeling* (Vol. I)—Prentice Hall, New York.
- Singh VP. 2010. *Environmental Hydrology*. Springer, New York.

I. Course Title : Soil and Water Conservation Structures

II. Course Code : SWCE 503

III. Credit Hours : 3(2+1)

IV. Aim of the course

To acquaint students with the planning and design of soil and water conservation structures, their stability checks and mechanized soil conservation techniques.

V. Theory

Unit I

Design, planning and layout of soil and water conservation structures. Criteria of selection of appropriate structures as per soil, land use and climatic conditions.

Unit II

Design and construction of earthen dam, stability analysis of land slopes and soil mass including landslides.

Unit III

Hydrological and structural design including stress analysis. Hydraulic jump and energy dissipaters for soil conservation structures.

Unit IV

Seepage through dams, flow net and determination of uplift pressure in drop structures, design of energy dissipaters.

Unit V

Design of water harvesting structures, construction, maintenance and utilization of stored water. Mechanized construction techniques for soil and water conservation structures.

VI. Practical

Numerical approach on probability distribution functions. Stability analysis and structural design of masonry water harvesting structures. Design of earthen dams and other energy dissipating structures. Cost analysis of water harvesting structures. Field visit to already constructed water harvesting structures in the nearby area/ watershed.

VII. Learning outcome

The student will be able to design the soil and water conservation structures as well as permanent gully control structures and water harvesting structures. They can have understanding of mechanized construction of soil and water conservation structures.

VIII. Lecture Schedule

S.No.	Topic	No. of Practicals
1	Introduction and need of Soil and Water Conservation in agricultural watershed	1
2	Runoff process and factors affecting it and estimation of runoff using various methods	3
3	Analysis of rainfall data, Probability concepts in the design of structures	3

4	Introduction, classification and functional requirement of soil and water conservation structures-Straight Drop spillway, chute spillway and drop inlet spillway	1
5	Specific energy and specific force	2
6	Hydraulic jump and its application, type of hydraulic jump, energy dissipation due to jump, jump efficiency, relative loss of energy	2
7	Straight drop spillway- Components and their functions, hydrologic, hydraulic and structural design	4
8	Drop inlet spillway- Components and their functions, hydrologic, hydraulic and structural design	2
9	Chute Spillway- Components and their functions, hydrologic, hydraulic and structural design	3
10	Criteria of selection of appropriate structures as per soil, land use and climatic conditions	1
11	Design of energy dissipaters in soil and water conservation structures	1
12	Introduction, types, design, criteria and construction of earthen dam, causes of failure of earthen dam, retaining wall and its design	3
13	Stability analysis of land slopes and soil mass including landslides, seepage control in earthen dams, flow net in earthen dams	2
14	Water harvesting: principles, importance and issues. Water harvesting techniques: classification based on source, storage and use. Runoff harvesting: short-term and long-term harvesting techniques, purpose and design criteria.	3
15	Mechanized construction techniques for soil and water conservation structures	1
	Total	**32**

IX. List of Practicals

S.No.	Topic	No. of Practicals
1.	Study of various probability distribution function for rainfall analysis	1
2.	Construction of specific energy and specific force diagram	2
3.	Measurement of hydraulic jump parameters and amount of energy dissipation	1
4.	Hydrologic and hydraulic design of a straight drop spillway	1
5.	Determination of uplift force and construction of uplift pressure diagram	1
6.	Determination of loads on headwall and construction of triangular load diagram	1
7.	Stability analysis of a straight drop spillway	1
8.	Hydraulic design of a chute spillway	1
9.	Design of drop inlet spillway	1
10.	Design of energy dissipating structures	1
11.	Design of earthen dam	1
12.	Seepage analysis in earthen embankment	1
13.	Design of water harvesting structures	1
14.	Economic analysis of water harvesting structures	1
15.	Field visit to already constructed water harvesting structures in the nearby area/ watershed.	1
	Total	**16**

X. Suggested Reading

- Mahnot SC, Singh PK and Chaplot PC. 2011. *Soil and Water Conservation and Water shed Management*. Apex Publishing House, Udaipur.
- Murty VVN. 1988. *Land and Water Management Engineering.* Second Edition Kalyani Publishers, New Delhi.
- Singh Gurmel C, Venkataraman G, Sastri and Joshi BP. 1991. *Manual of Soil and Water conservation Practices*. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi.
- Singh PK. 2000. *Watershed Management* (*Design and Practice*). e-media publications, Udaipur.
- Suresh R. 2006. *Soil and Water Conservation Engineering*. Fourth Edition Standard Publishers and Distributors, Delhi.
- Singh Raj Vir. 2003. *Watershed Management*. Second Edition, Yash Publishing, Bikaner.

I. Course Title : Watershed Management and Modeling

II. Course Code : SWCE 505

III. Credit Hours : 3(2+1)

IV. Aim of the course

To acquaint students with watershed management concept and its benefit for sustainable rural development through participatory approach, including environmental impact as well as policy frame work.

V. Theory

Unit I

Concept of watershed, its hydrological and geomorphological characteristics. Status of watershed management programs in India. Problems of desertification and degradation.

Unit II

Concept of watershed management and sustainability, participatory approach and operational watershed. Surveys, monitoring, reclamation and conservation of agricultural and forest watersheds, hill slopes and ravines.

Unit III

Watershed management research instrumentation and measurement, problem identification, simulation and synthesis. Rainfed farming and drought management. Modeling of flood and drought phenomenon.

Unit IV

Use of Remote Sensing and GIS in watershed management and modeling. Watershed modeling approaches, mathematical bases and structure of existing watershed models.

Unit V

Environmental impact assessment of watersheds. Quantitative evaluation of management techniques. National land use policy, legal and social aspects. Case studies of watershed management.

VI. Practical

Selection and delineation of a watershed. Benchmark surveys. Preparation of watershed land use map. Preparation of watershed development proposal. Preparation of watershed evaluation and impact assessment report. Application of watershed models for evaluation of conservation treatments. Use of Remote Sensing and GIS in watershed management and modeling.

VII. Learning outcome

The students will be able to understand different conservation practices and their effect on watershed behavior. They can also estimate the geomorphologic parameters of particular watershed which is quite useful for watershed planning and development of watershed models.

VIII. Lecture Schedule

S.No.	Topic	No. of Lectures
1	Concept of watershed, its hydrological and geomorphological characteristics	2
2	Status of watershed management programs in India	2
3	Problems of desertification and degradation	2
4	Concept of watershed management and sustainability, participatory approach and operational watershed	3
5	Surveys, monitoring, reclamation and conservation of agricultural and forest watersheds, hill slopes and ravines	3
6	Watershed management research instrumentation and measurement, problem identification, simulation and synthesis	2
7	Rainfed farming and drought management	2
8	Modeling of flood and drought phenomenon	2
9	Use of Remote Sensing and GIS in watershed management and modeling	2
10	Watershed modeling approaches, mathematical bases and structure of eXisting watershed models	3
11	Environmental impact assessment of watersheds	2
12	Quantitative evaluation of management techniques	2
13	National land use policy, legal and social aspects	2
14	Case studies of watershed management	3
	Total	**32**

IX. List of Practicals

S.No.	Topic	No of Practicals
1	Selection and delineation of a watershed	3
2	Benchmark surveys	2
3	Preparation of watershed land use map	2
4	Preparation of watershed development proposal	3
5	Preparation of watershed evaluation and impact assessment report	2
6	Application of watershed models for evaluation of conservation treatments	2
7	Use of Remote Sensing and GIS in watershed management and modelling	2
	Total	**16**

X. Suggested Reading

- Dhaliwal GS Hansra BS and Ladhar SS. 1993. Wetlands, their Conservation and Management. Punjab Agricultural University, Ludhiana.
- Dhruvanarayana VV, Sastry G and Patnaik US. Watershed Management. Publ. and Inf. Dv., ICAR, Krishi Anusandhan Bhavan, New Delhi.
- Singh RV. 2000. Watershed Planning and Management. Second Edition Yash Publishing House, Bikaner.
- Suresh R. 2017. Watershed Planning and Management. Standard Publication and Distribution, Delhi.
- Tideman EM. 1999. Watershed Management (Guidelines for Indian Conditions). Omega Scien tific Publishers, New Delhi.

I. Course Title : Dryland Water Management Technologies

II. Course Code : SWCE 510

III. Credit Hours : 2(2+0)

IV. Aim of the course

To provide detail knowledge about analysis of severity of drought assessment and various dry land water management technologies suitable for conservation, harvesting and enhancing productivity of rainfed areas.

V. Theory

Unit I

Drought severity assessment: Meteorological, hydrological and agricultural methods. Drought indices. GIS based drought information system, drought vulnerability assessment and mapping using GIS. DPAP programme, drought monitoring 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 II

Stress physiology and crop 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 III

Land shaping and land development for soil moisture conservation. Improvement of tillage and soil management by implements and engineering practices. Soil and moisture conservation for rainfed lands through improved implements and engineering practices. Gel technology.

Ex-situ measures: Water harvesting-micro catchments. Design of small water harvesting structures: Farm Ponds, percolation tanks their types and design, recycling of runoff water for crop productivity.

Unit IV

Crops and cropping practices related to soil and moisture conservation. Fertility management in dryland farming. Planning and development of watersheds from engineering view point. Case studies.

Unit V

Application of aerial photography in surveys and planning of watersheds for rainfed agriculture. Use of Remote Sensing in soil moisture estimation.

VI. Learning outcome

The students will be able to understand drought severity assessment techniques alongwith new and appropriate methods of rainwater conservation and harvesting technologies for rainfed areas.

VII. Lecture Schedfule

S.No.	Topic	No. of Lectures
1.	Drought severity assessment: Meteorological, hydrological and agricultural methods	2
2.	Drought indices	1
3.	GIS based drought information system, drought vulnerability assessment and mapping using GIS	2
4.	DPAP programme, drought monitoring constraints, limiting crop production in dry land areas	2
5.	Types of drought: characterization of environment for water availability	1
6.	Types of drought: crop planning for erratic and aberrant weather conditions	1
7.	Stress physiology and crop resistance to drought	1
8.	Adaptation of crop plants to drought and drought management strategies	1
9.	Preparation of appropriate crop plans for dry land areas	2
10.	Mid contingent plan for aberrant weather conditions	1
11.	Land shaping and land development for soil moisture conservation	1
12.	Improvement of tillage and soil management by implements and engineering practices	2
13.	Soil and moisture conservation for rainfed lands through improved implements and engineering practices	2
14.	Introduction of Gel technology for conservation measures	1
15.	Ex-situ measures: Water harvesting-micro catchments	1
16.	Design of small water harvesting structures: Farm Ponds	1
17.	Design of small water harvesting structures: percolation tanks their types and design	2
18.	Recycling of runoff water for crop productivity	1
19.	Crops and cropping practices related to soil and moisture conservation	1
20.	Fertility management in dryland farming	1
21.	Planning and development of watersheds from engineering view point	2
22.	Planning and development of watersheds - Case studies	1
23.	Application of aerial photography in surveys and planning of watersheds for rainfed agriculture	1
24.	Use of Remote Sensing in soil moisture estimation	1
	Total	**32**

VIII. Suggested Reading

- Das NR. 2007. Tillage and Crop Production. Scientific Publishers.
- Dhopte AM. 2002. Agro Technology for Dryland Farming. Scientific Publ.

- Gupta US. 1995. Production and Improvements of Crops for Drylands. OXford & IBH
- Singh RP. 1988. Improved Agronomic Practices for Dryland Crops. CRIDA.
- Singh RP. 2005. Sustainable Development of Dryland Agriculture in India. Scientific Publ.
- Singh RV. 2003. Watershed Planning and Management. Second Edition. Yash Publishing House, Bikaner .
- Singh SD. 1998. Arid Land Irrigation and Ecological Management. Scientific Publishers.

Supporting Courses

SUPPORTING COURSES

Course Title with Credit Load

Course Code	Course Title	Credit Hours
STAT 501	MATHEMATICS FOR APPLIED SCIENCES	2(2+0)
STAT 502	STATISTICAL METHODS FOR APPLIED SCIENCES	4(3+1)
STAT 511	EXPERIMENTAL DESIGNS	3(2+1)
STAT 512	BASIC SAMPLING TECHNIQUES	3(2+1)
STAT 521	APPLIED REGRESSION ANALYSIS	3(2+1)
STAT 522	DATA ANALYSIS USING STATISTICAL PACKAGES	3(2+1)
MCA 501	COMPUTERS FUNDAMENTALS AND PROGRAMMING	3(2+1)
MCA 502	COMPUTER ORGANIZATION AND ARCHITECTURE	2(2+0)
MCA 511	INTRODUCTION TOCOMMUNICATION	
	TECHNOLOGIES, COMPUTER NETWORKING AND	
	INTERNET	2(1+1)
MCA 512	INFORMATION TECHNOLOGY IN AGRICULTURE	2(2+0)
BCM 501	BASIC BIOCHEMISTRY	4(3+1)
BCM 505	TECHNIQUES IN BIOCHEMISTRY	4(2+2)
FOR 511	GENERAL STATISTICAL METHODS AND COMPUTER	
	APPLICATIONS	3(2+1)
FOR 610	RESEARCH METHODOLOGY IN FORESTRY	3(2+1)
FOR 611	RESEARCH AND PUBLICATION ETHICS	2(1+1)

Course Contents

Course Title : Mathematics for Applied Sciences

I. Course Code : STAT 501

II. Credit Hours : 2(2+0)

III. Aim of the course

This course is meant for students who do not have sufficient background of Mathematics. The students would be exposed to elementary mathematics that would prepare them to study their main courses that involve knowledge of Mathematics. The students would get an exposure to Linear Algebra, differentiation, integration and differential equations etc.

IV. Theory

Unit I

Set theory-set operations, finite and infinite sets, operations of set, function.

Unit II

Vectors and vector spaces, Matrices notations and operations, laws of matrix algebra; transpose and inverse of matrix, Eigen values and Eigen vectors. Determinants - evaluation and properties of determinants, Solutions of Linear Equations.

Unit III

Variables and functions, limits and continuity of specific functions. Differentiation: theorems of differentiation, differentiation of logarithmic, trigonometric, exponential and inverse functions, Differentiation of function of a function, derivatives of higher order, partial derivatives. Application of derivatives, determination of points of inflexion, maxima and minima.

Unit IV

Integration, methods of integration, reduction formulae, definite and indefinite integral, Applications of integration in Agriculture, Differential Equations.

V. Suggested Reading

- Hohn FE. 2013. Elementary Matrix Algebra, 3rd Ed., Kindle Edition
- Harville D.A. 1997. Matrix Algebra from a Statistician's Perspective. Springer.
- Hohn F.E. 1973. Elementary Matrix Algebra. Macmillan.
- Searle S.R. 1982. Matrix Algebra Useful for Statistics. John Wiley. Stewart J. 2007. Calculus. Thompson.
- Thomas G.B. Jr. and Finney R.L. 1996. Calculus. 9th Ed. Pearson Edu.

Course Title : Statistical Methods for Applied Sciences

I. Course Code : AST 502

II. Credit Hours : 4(3+1)

III. Aim of the course

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.

IV. Theory

Unit I

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.

Unit III

Introduction to theory of estimation and confidence-intervals, Simple and multiple correlation coefficient, partial correlation, rank correlation, Simple and multiple linear regression model, test of significance of correlation coefficient and regression coefficients, Coefficient of determination, Fitting of quadratic models.

Unit IV

Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Run test for the randomness of a sequence. Median test.

Unit V

Introduction to ANOVA: One way and Two Way, Introduction to Sampling Techniques, Introduction to Multivariate Analysis, Transformation of Data.

V. Practical

- Exploratory data analysis, 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 Correlation and regression analysis, fitting of Linear and Quadratic Model.
- Non-parametric tests. ANOVA: One way, Two Way, SRS.

VI. Suggested Reading

- Goon A.M, Gupta M.K and Dasgupta B. 1977. An Outline of Statistical Theory. Vol. I. The World Press.
- Goon A.M, Gupta M.K. and Dasgupta B. 1983. Fundamentals of Statistics. Vol. I. The World Press.
- Hoel P.G. 1971. Introduction to Mathematical Statistics. John Wiley.
- Hogg R.V and Craig T.T. 1978. Introduction to Mathematical Statistics. Macmillan.
- Morrison D.F. 1976. Multivariate Statistical Methods. McGraw Hill.
- Hogg RV, McKean JW, Craig AT. 2012. Introduction to Mathematical Statistics 7th Edition.
- Siegel S, Johan N & Casellan Jr. 1956. Non-parametric Tests for Behavior Sciences. John Wiley.
- Anderson TW. 2009. An Introduction to Multivariate Statistical Analysis, 3rd Ed . John Wiley
- http://freestatistics.altervista.org/en/learning.php.
- http://www.statsoft.com/textbook/stathome.html.

I. Course Title : Experimental Designs

II. Course Code : STAT 511

III. Credit Hours : 3(2+1)

IV. Aim of the course

This course is meant for students of agricultural and animal sciences other than Agricultural 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.

V. 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. Concept of confounding.

Unit IV

Split plot and strip plot designs, analysis of covariance and missing plot techniques in randomized block and Latin square designs; Transformations, Balanced Incomplete Block Design, resolvable designs and their applications, Lattice design, alpha design - concepts, randomization procedure, analysis and interpretation of results. Response surfaces. Combined analysis.

VI. 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,
- Analysis with missing data,
- Split plot and strip plot designs.

VII. Suggested Reading

- Cochran WG and Cox GM. 1957. Experimental Designs. 2nd Ed. John Wiley.
- Dean AM and Voss D. 1999. Design and Analysis of Experiments. Springer.
- Montgomery DC. 2012. Design and Analysis of Experiments, 8th Ed. John Wiley.
- Federer WT. 1985. Experimental Designs. MacMillan.
- Fisher RA. 1953. Design and Analysis of Experiments. Oliver & Boyd.
- Nigam AK and 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.
- www.drs.icar.gov.in.

I. Course Title : Basic Sampling Techniques

II. Course Code : STAT 512

III. Credit Hours : 3(2+1)

IV. Aim of the course

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.

V. 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 PPS sampling,

Unit IV

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

VI. 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.

VII. 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

I. Course Title : Applied Regression Analysis

II. Course Code : STAT 521

III. Credit Hours : 3(2+1)

IV. Aim of the course

This course is meant for students of all disciplines including agricultural and animal sciences. The students would be exposed to the concepts of correlation and regression. Emphasis will be laid on diagnostic measures such as autocorrelation, multi collinearity and heteroscedasticity. This course would prepare students to handle their data for analysis and interpretation.

V. Theory

Unit I

Introduction to correlation analysis and its measures, Correlation from grouped data, correlation, Rank correlation, Testing of population correlation coefficients; Multiple and partial correlation coefficients and their testing.

Unit II

Problem of correlated errors; Auto correlation; Heteroscedastic models, Durbin Watson Statistics; Removal of auto correlation by transformation; Analysis of collinear data; Detection and correction of multi collinearity, Regression analysis; Method of least squares for curve fitting; Testing of regression coefficients; Multiple and partial regressions.

Unit III

Diagnostic of multiple regression equation; Concept of weighted least squares; regression equation on grouped data; Various methods of selecting the best regression equation.

Unit IV

Concept of nonlinear regression and fitting of quadratic, exponential and power curves; Economic and optimal dose, Orthogonal polynomial.

VI. Practical

- Correlation coefficient, various types of correlation coefficients, partial and multiple, testing of hypotheses;
- Multiple linear regression analysis, partial regression coefficients, testing of hypotheses, residuals and their applications in outlier detection;
- Handling of correlated errors, multi collinearity;
- Fitting of quadratic, exponential and power curves, fitting oforthogonal polynomials.

VII. Suggested Reading

- Kleinbaum DG, Kupper LL, Nizam A. 2007. Applied Regression Analysis and Other Multivariable Methods (Duxbury Applied) 4th Ed.
- Draper NR and Smith H. 1998. Applied Regression Analysis. 3rd Ed. John Wiley.
- Ezekiel M. 1963. Methods of Correlation and Regression Analysis. John Wiley.
- Koutsoyiannis A. 1978. Theory of Econometrics. MacMillan.
- Kutner MH, Nachtsheim CJ and Neter J. 2004. Applied Linear Regression Models. 4th Ed. With Student CD. McGraw Hill.

I. Course Title : Data Analysis Using Statistical Packages

II. Course Code : STAT 522

III. Credit Hours : 3(2+1)

IV. Aim of the course

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

V. Theory

Unit I

Introduction to various statistical packages: Excel, R, SAS, SPSS. Data Preparation; Descriptive statistics; Graphical representation of data, Exploratory data analysis.

Unit II

Test for normality; Testing of hypothesis using chi-square, t and F statistics and Z-test.

Unit III

Data preparation for ANOVA and ANCOVA, Factorial Experiments, contrast analysis, multiple comparisons, Analyzing crossed and nested classified designs.

Unit IV

Analysis of mixed models; Estimation of variance components; Correlation and regression analysis, Probit, Logit and Tobit Models.

Unit V

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

VI. Practical

- Use of software packages for summarization and tabulation of data, obtaining descriptive statistics, graphical representation of data;
- Testing the hypothesis for one sample t-test, two sample t-test, paired t-test, test for large samples - Chi-squares test, F test, one-way analysis of variance;
- Designs for Factorial Experiments, fixed effect models, random effect models, mixed effect models, estimation of variance components;
- Linear regression, Multiple regression, Regression plots;
- Discriminant analysis - fitting of discriminant functions, identification of important variables;
- Factor analysis. Principal component analysis - obtaining principal component.

VII. Suggested Reading

- Anderson C.W. and Loynes R.M. 1987. The Teaching of Practical Statistics. John Wiley.
- Atkinson A.C. 1985. Plots Transformations and Regression. Oxford University Press.
- Chambers J.M., Cleveland W.S., Kleiner B and Tukey P.A. 1983. Graphical Methods for Data Analysis. Wadsworth, Belmount, California.
- Chatfield C. 1983. Statistics for Technology. 3rd Ed. Chapman & Hall. Chatfield C. 1995. Problem Solving: A Statistician's Guide. Chapman & Hall.
- Cleveland W.S. 1985. The Elements of Graphing Data. Wadsworth, Belmont, California.
- Ehrenberg ASC. 1982. A Primer in Data Reduction. John Wiley.
- Erickson B.H. and Nosanchuk T.A. 1992. Understanding Data. 2nd Ed. Open University Press, Milton Keynes.
- Snell E.J. and Simpson HR. 1991. Applied Statistics: A Handbook of GENSTAT Analyses. Chapman and 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 and 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.
- Cleveland WS. 1994. The Elements of Graphing Data, 2nd Ed., Chapman & Hall
- http://freestatistics.altervista.org/en/learning.php.
- http://freestatistics.altervista.org/en/stat.php.
- http://www.cas.lancs.ac.uk/glossary_v1.1/main.html.
- http://www.stat.sc.edu/~grego/courses/stat706/.
- www.drs.icar.gov.in.

I. Course Title : Computer Fundamentals and Programming

II. Course Code : MCA 501

III. Credit Hours : 3(2+1)

IV. Aim of the course

This is a course on Computer Fundamentals and Programming that aims at exposing the students to understand how computer works, analytical skills to solve problems using computers. andto write computer programs using C.

V. Theory

Unit I

Functional units of computer, I/O devices, primary and secondary memories. Number systems: decimal, octal, binary and hexadecimal; Representation of integers, fixed and floating point numbers, Operator precedence, character representation; ASCII, Unicode.

Unit II

Programming Fundamentals with C - Algorithm, techniques of problem solving, flowcharting, stepwise refinement; Constants and variables; Data types: integer, character, real, data types; Arithmetic expressions, assignment statements, logical expressions. Control flow

Unit III

Arrays and structures. Pointers, dynamic memory allocations

Unit IV

Program Structures – functions, subroutines

Unit V

I/O operations, Program correctness; Debugging and testing of programs.

VI. Practical

- Conversion of different number types;
- Creation of flow chart, conversion of algorithm/flowchart to program;
- Mathematical operators, operator precedence;
- Sequence, control and iteration;
- Arrays and string processing;
- Matrix operations, Sorting, Pointers and File processing – Reading and writing teXt files.

VII. Suggested Reading

- Balaguruswamy E. 2019. Programming with ANSI C. Tata McGraw Hill.
- Gottfried B. 2017. Programming with C, Schaum Outline Series. Tata McGraw Hill.
- Kanetkar Y. 1999. Let Us C. BPB Publ.
- Malvino A.P. and Brown J.A.. 2017. Digital Computer Electronics. Tata McGrawHill.
- Mano M.M. 1999. Digital Logic and Computer Design. Prentice Hall of India.

I. Course Title : Computer Organization and Architecture

II. Course Code : MCA 502

III. Credit Hours : 2(2+0)

IV. Aim of the course

This is a course on Computer Organization and Architecture that aims at exposing the students to understand basic knowledge of how computer works.

V. Theory

Unit I

Number systems; Boolean algebra - minimization of Boolean function using KarnaughMap.

Unit II

Logic Gates, Combinational circuits – multiplexer, de-multiplexer, encoder, decoder; Sequential circuits: Flip-flops, Half and Full adder, Shift register, Counters.

Unit III

Organization of CPU, Control Unit- Instruction and Execution cycle in CPU, Register Organization, The Instruction Cycle, Instruction Pipelining.

Unit IV

Memory organization - Internal memory: Semiconductor Main Memory (RAM, ROM,EPROM), Cache Memory, Advanced DRAM Organization; Magnetic Disks, RAID, Optical Memory, Magnetic Tape.

Unit V

Memory -Basic structure of computer hardware and system software - Addressing methods and machine programme sequencing; Input-output organizations - accessing I/O devices - direct memory access (DMA) – interrupts.

Unit VI

Introduction to microprocessors – CISC and RISC Architecture, Study of functional units of microprocessors.

VI. Suggested Reading

- Gear C.W. 1974. Computer Organization and Programming. McGraw Hill.
- Hayes J.P. 1988. Computer Architecture and Organisation. McGraw Hill.
- Malvino A.P and Brown J.A. 1999. Digital Computer Electronics. Tata McGraw Hill.
- Mano M.M. 1999. Digital Logic and Computer Design. Prentice Hall of India.
- Mano M.M. 2007. Computer System Architecture. Prentice Hall of India.
- Stallings W. 2016. Computer Organization and Architecture: Designing for Performance. Pearson Edu.

I. Course Title : Introduction to Communication Technologies, Computer Networking and Internet

II. Course Code : MCA 511

III. Credit Hours : 2(1+1)

IV. Aim of the course

This is a course on Introduction to Networking and Internet Applications that aims at exposing the students to understand Computer networking and web applications development.

V. Theory

Unit I

Networking fundamentals, types of networking, network topology; Introduction to File Transfer Protocol (FTP), Telnet, Simple Mail Transfer Protocol (SMTP), Internet Protocol v4 & v6. Network infrastructure and Security-switches, routers, firewall, intranet, internet, Virtual Private Network

Unit II

World Wide Web (www), working with Internet; Web pages, web sites, web servers; Web Applications.

Unit III

Hyper Text Markup Language (HTML), DHTML, web based application development. Static websites, dynamic websites. Client Side processing – scripting languages, Jquery. Server Side processingASP.NET/JSP

VI. Practical

- Network and mail configuration;
- Using Network Services;
- Browsing of Internet;
- Creation of web pages;
- Creation of websites using HTML and scripting languages.

VII. Suggested Reading

- Cox V, Wermers L and Reding E.E. 2006. HTML Illustrated Complete. 3rd Ed. Course Technology.
- Niederst J. 2001. Web Design in a Nutshell. O'Reilly Media.
- Tanenbaum A.S. 2003. Computer Networks. Prentice Hall of India.

I. Course Title : Information Technology in Agriculture

II. Course Code : MCA 512

III. Credit Hours : 2(2+0)

IV. Aim of the course

This is a course on Introduction to Networking and Internet Applications that aims at exposing the students to understand analogy of computer, basic knowledge of MS Office. Also to understand Internet and WWW, use of IT application and different IT tools in Agriculture

V. Theory

Unit I

Introduction to Computers, Anatomy of computer, Operating Systems, definition and types, Applications of MS Office for document creation & Editing, Data presentation, interpretation and graph creation, statistical analysis, mathematical expressions,

Unit II

Database, concepts and types, uses of DBMS in Agriculture, World Wide Web (WWW): Concepts and components, Introduction to computer programming languages, concepts and standard input/output operations. e-Agriculture, concepts and applications,

Unit III

Use of ICT in Agriculture, Computer Models for understanding plant processes. IT application for computation of water and nutrient requirement of crops, Computer- controlled devices (automated systems) for Agri-input management, Smartphone Apps in Agriculture for farm advises, market price, postharvest management etc.,

Unit IV

Geospatial technology for generating valuable agri-information. Decision support systems, concepts, components and applications in Agriculture, Agriculture Expert System, Soil Information Systems etc. for supporting Farm decisions, Preparation of contingent crop-planning using IT tools.

VI. Suggested Reading

- Vanitha G. 2011. Agro-informatics
- http://www.agrimoon.com
- http://www.agriinfo.in
- http://www.eagri.org
- http://www.agriglance.com
- http://agritech.tnau.ac.in

I. Course Title : Basic Biochemistry

II. Course Code : BCM 501

III. Credit Hours : 4(3+1)

IV. Why this course?

To impart the fundamental knowledge on structure and function of cellular components involved in biological processes and an elementary introduction to the study of molecular biology.

V. Aim of the course

The course is designed to provide elementary knowledge/overview of structure and function of proteins, carbohydrates, lipids, nucleic acids and other biomolecules and their metabolism.

No.	Blocks	Units
1.	Introduction to Biochemistry	1. Scope and importance of biochemistry
		2. Foundation of life
		3. Water
		4. Physical techniques for structure determination
2.	Structure and function of biomolecules	1. Biomolecules
		2. Immunoglobulins and PR proteins
		3. Plant secondary metabolites
3.	Metabolism – the basics	1. Molecules aiding metabolism
		2. Thermodynamics –principles and energetic of life
4.	Catabolism and its regulation	1. Catabolism of energy molecules
		2. ATP formation
5.	Fundamentals of Molecular biology	1. Molecular biology processes and genetic engineering
		2. Recombinant DNA technology

VI. Theory

Block 1: Introduction to Biochemistry

Unit 1: Scope and importance of biochemistry (1 Lecture)

Biochemistry as modern science and its various divisions, Scope and importance of biochemistry in agriculture and allied sciences.

Unit 2: Foundation of life (2 Lectures)

Fundamental principles governing life, supramolecular structures, significance of weak non covalent interactions in biology.

Unit 3: Water (3 Lectures)

Structure of water, ionization of water, acid base concept, pH and buffers, significance of structure-function relationship.

Unit 4: Physical techniques for structure determination (2 Lectures)

General introduction to physical techniques for determination of structure of biopolymers.

Block 2: Structure And Function of Biomolecules

Unit 1: Biomolecules (10 Lectures)

Structure, classification, properties and function of carbohydrates, amino acids, proteins, lipids and nucleic acids.

Unit 2: Immunoglobulins and PR proteins (2 Lectures)

Structure, formation and different forms of immunoglobulins, PR proteins and their classification.

Unit 3: Plant secondary metabolites (3 Lectures)

Structure, classification and function of plant secondary metabolites.

Block 3: Metabolism – The Basics

Unit 1: Molecules aiding metabolism (2 Lectures)

Structure and biological functions of vitamins and coenzymes, enzymes: classification and mechanism of action; regulation, factors affecting enzyme action. Hormones: animal and plants.

Unit 2: Thermodynamics –principles and energetic of life (2 Lectures)

Fundamentals of thermodynamic principles applicable to biological processes, Bioenergetics.

Block 4: Catabolism and its Regulation

Unit 1: Catabolism of energy molecules (5 Lectures)

Important and basic degradative metabolic pathways of carbohydrates, lipids and proteins and their regulation.

Unit 2: ATP formation (3 Lectures)

Formation of ATP, substrate level phosphorylation, electron transport chain and oXidative phosphorylation, chemiosmotic theory and proton motive force.

Block 5: Fundamentals of Molecular Biology and Genetic Engineering

Unit 1: Molecular biology processes (4 Lectures)

Overview of replication, transcription and translation.

Unit 2: Recombinant DNA technology (3 Lectures)

Restriction enzymes, DNA cloning, applications of cloning, transgenics.

VII. Practicals

- Preparation of standard and buffer solutions
- Detection of carbohydrates, amino acids and proteins
- Extraction and estimation of sugars
- Extraction and estimation of amino acids
- Extraction and estimation of proteins
- Estimation of acid value of fat/oil
- Estimation of peroxide value of fat/oil
- Estimation of saponification value in fats and oils
- Fatty acid composition in fat/oil by GC
- Estimation of DNA and RNA by spectroscopic methods
- Estimation of Ascorbic acid
- Separation of biomolecules by TLC and Paper chromatography
- Estimation of alpha amylase activity
- Qualitative tests for secondary plant metabolites.

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)

– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz

IX. Learning outcome

With this course, the students are expected to be able to understand the actual chemical concepts and fundamental processes of biology at molecular level.

X. Suggested Reading

- Nelson DL and Cox MM. 2017. Lehninger Principles of Biochemistry. 7th edition. W. H. Freeman & Co Ltd
- Satyanarayana U and Chakrapani U. 2017. Biochemistry. 5th edition, Elsevier
- Moran LA, Horton HR, Scrimgeour KG and Perry MD. 2012. Principles of Biochemistry. 5th edition Pearson.
- Voet D and Voet JG. 2011. Biochemistry. 4th edition John Wiley.
- Pratt CW and Cornely K. 2014. Essential Biochemistry. 3rd Edition. Wiley
- Moorthy K. 2007. Fundamentals of Biochemical Calculations. 2nd edition. CRC Press
- Conn EE, Stumpf PK, Bruening G and Doi RH. 2006. Outlines of Biochemistry. 5th edition. Wiley.

I. Course Title : Techniques in Biochemistry

II. Course Code : BIOCHEM 505

III. Credit Hours : 4(2+2)

IV. Why this course?

Biochemical studies rely on the availability of appropriate analytical techniques and their applications. This course will examine modern methods and technologies that are used in biochemical analysis with emphasis on instrumentation, underlying principles, aims, strategies and current applications.

V. Aim of the course

To provide hands-on eXperience to different biochemical techniques commonly used in research along with the knowledge on principles and the instrumentation.

No.	Blocks	Units
1.	Separation techniques	1. Chromatography techniques
		2. Electrophoretic technique
		3. Hydrodynamic methods
		4. Centrifugation
2.	Spectroscopic techniques	1. Spectrophotometry
		2. Mass spectroscopy
		3. Atomic absorption spectrophotometry
3.	Microscopy	1. Microscopic techniques
4.	Tracer, imaging, immunochemical	1. Tracer techniques and other techniques
		2. Imaging techniques

3. Immunochemical techniques
4. Other techniques

VI. Theory

Block 1: Separation Techniques

Principles and applications of separation techniques.

Unit 1: Chromatography techniques (4 Lectures)

Principles and applications of paper, thin layer, gel filtration, ion-exchange, affinity, column & HPTLC, GC, HPLC and FPLC.

Unit 2: Electrophoretic technique (2 Lectures)

General principles,paper and gel electrophoresis, native and SDS-PAGE, 2D-PAGE, capillary electrophoresis.

Unit 3: Hydrodynamic methods (2 Lectures)

Hydrodyanmic methods of separation of biomolecules such as viscosity and sedimentation velocity, - their principles.

Unit 4: Centrifugation (2 Lectures)

Basic principles of sedimentation, type, care and safety aspects of centrifuge preparative and analytical centrifugation.

Block 2: Spectroscopic Techniques

Unit 1: Spectrophotometry (3 Lectures)

Principles and applications of UV-visible, Fluorescence, IR and FTIR, Raman, NMR and FTNMR, ESR and X-Ray spectroscopy.

Unit 2: Mass spectroscopy (3 Lectures)

MS/MS, LC-MS, GC-MS, MALDI-TOF, applications of mass spectrometry in biochemistry.

Unit 3: Atomic absorption spectrophotometry (2 Lectures)

Principle, function and instrumentation ofatomic absorption spectrophotometry.

Block 3. Microscopy

Unit 1: Microscopic techniques (2 Lectures)

Principles and applications, light, UV, phase contrast, fluorescence and electron microscopy, flow cytometry.

Block 4: Tracer, Imaging, Immunochemical and Other Techniques

Unit 1: Tracer technique (2 Lectures)

Tracer techniques in biology: concept of radioactivity, radioactivity counting methods with principles of different types of counters, concept of á, â and ã emitters, scintillation counters, J-ray spectrometers, autoradiography, applications of radioactive tracers in biology.

Unit 2: Imaging techniques (2 Lectures)

Principles and applications of phosphor imager, MRI and CT scan.

Unit 3: Immunochemical technique (2 Lectures)

Production of antibodies, immunoprecipitation, immunoblotting, immunoassays, RIA and ELISA.

Unit 4: Other techniques (2 Lectures)

Cryopreservation, polymerase chain reaction (PCR), FACS.

VII. Practicals

- Expression of concentration in terms of dilution, molarity, normality, percent expression
- pH measurement and buffer preparation
- Determination of absorption maxima of biomolecules
- Estimation of biomolecules through spectrophotometry and other methods
- Separation of carbohydrates and amino acids by paper chromatography
- Separation and analysis of fatty acids/lipids by GC
- Separation/estimation of biomolecules through HPLC and FPLC
- Separation of proteins using ion exchange, gel filtration and affinity chromatography
- Electrophoretic separation of proteins and nucleic acids
- Centrifugation- differential and density gradient
- $(NH_4)_2SO_4$ precipitation and dialysis
- Use of radioisotopes in metabolic studies
- PCR
- ELISA
- Western blotting/ Dot blotting

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

At the end of the course, the student will acquire the basic knowledge of the main biochemical methods used in the separation, identification, characterization and analysis of biomolecules.

X. Suggested Reading

- Boyer R. 2011. Biochemistry Laboratory: Modern Theory and Techniques 2nd Edition. Pearson
- Hofmann A and Clokie S. 2010. Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology. 7th edition. Cambridge University Press.
- Sawhney SK and Singh R. 2000. Introductory Practical Biochemistry. 2nd Ed. Narosa
- Katoch R. 2011. Analytical Techniques in Biochemistry and Molecular Biology. Springer

- Boyer R. 2009. Modern Experimental Biochemistry. Fifth impression. Pearson
- Lottspeich F and Engels JW. (Eds). 2018. Bioanalytics: Analytical Methods and Concepts in Biochemistry and Molecular Biology. Wiley-VCH
- Wilson K and Walker J. 2010. Principles and Techniques of Biochemistry and Molecular Biology, 7th Edition. Cambridge University Press

I. Course Title : General Statistical Methods and Computer Applications

II. Course Code : FOR 511

III. Credit Hours : 3(2+1)

IV. Aim of the course

This course is meant for students who do not have sufficient background of statistical methods. The students would be exposed to concepts of general statistical methods and statistical inference that would help them in understanding the importance of statistical methodology. It would also help them in understanding the concepts involved in data presentation, analysis and interpretation of results.

V. Theory

Unit I

Review of probability. Random variable and mathematical expectation. Discrete and continuous probability distributions, viz., Binomial, Poisson and Normal distributions.

Unit II

Correlation and regression, Rank correlation, Non-linear regression, Partial and multiple correlation coefficient, Intra class correlation,Multiple linear regression.

Unit III

Introduction to theory of estimation, Testing of statistical hypothesis: chi-square, t and F distributions. Tests of significance based on chi-square, t and F tests. Large sample tests, Fisher Z transformation.

Unit IV

Analysis of variance: One way and two way classification. Design of Experiments: Basic Principles of design of experiments, Completely Randomised Design, Randomised Block Design, Latin Square Design. Elementary idea of factorial experiments. Estimation of genetic parameters from ANOVA table.

Unit V

Non-parametric tests: Sign test, Wilcoxon test, Mann-Whitney U-test, Wald Wolfowitz run test, Median test, Kruskal- Wallis test. MS Excel, Introduction to computer softwares.

VI. Practical

- Random variable and mathematical expectation;
- Fitting of distributions, viz., Binomial, Poisson, Normal;
- Correlation and regression;
- Non-linear regression;

- Multiple linear regression;
- Testing of hypothesis based on chi square, t and F tests. Large sample tests. Completely Randomised Design, Randomised Block Design, Latin Square Design and Factorial experiments. Non-parametric tests. Exercises based on computer software.

VII. Suggested Reading

- Aggarwal BL. 1996. Basic Statistics. Wiley Eastern Limited, New Age International Ltd. Bansal ML, Singh S, Singh TP and Kumar R. 2004. Statistical Methods for Research Workers.
- Kalyani Publishers.
- Chandel SRS. 2014. A Handbook of Agricultural Statistics. Achal Prakashan.
- Goon AM, Gupta MK and Dasgupta B. 1968. Fundamentals of Statistics, vol I, II. The World Press, Calcutta.
- Snedecor GW and Cochran WG. 1980. Statistical Methods. East West Press.

Lecture Schedule

Sr.No.	Topic	No. of Lecture(s)
	Theory	
1.	Review of probability. Addition and multiplication law of probability	2
2.	Random variable and mathematical expectation	1
3.	Discrete and continuous probability distributions: Binomial, Poisson and Normal distributions	4
4.	Correlation and regression. Rank correlation	2
5.	Non-linear regression	1
6.	Partial correlation coefficient, multiple correlation coefficient, Multiple linear regression. Intra class correlation	4
7.	Introduction to theory of estimation	1
8.	Testing of statistical hypothesis: chi-square, t and F distributions. Tests of significance based on chi-square, t and F tests. Large sample test. Fisher z transformation	5
9.	Analysis of variance: One way and two way classification	2
10.	Design of Experiments: Basic Principles of design of experiments, Completely randomised design, Randomised block design, Latin square design	4
11.	Elementary idea of Factorial experiments. Estimation of genetic parameters from ANOVA table	3
12.	Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Wald Wolfowitz run test, Median test, Kruskal- Wallis test	2
13.	MS Excel, Introduction to computer software	2
	Total	**33**
	Practical	
1.	Random variable and mathematical expectation	1
2.	Discrete and continuous probability distributions: Binomial, Poisson and Normal distributions	2
3.	Correlation and regression. Rank correlation	1

4.	Non-linear regression	1
5.	Multiple linear regression. Intra class correlation	2
6.	Tests based on chi-square, t and F tests. Large sample test	2
7.	Analysis of variance: One way and two way classification	1
8.	Design of Experiments: Basic Principles of design of experiments, Completely randomised design, Randomised block design, Latin square design	2
9.	Elementary idea of Factorial experiments. Estimation of genetic parameters from ANOVA table	1
10.	Non-parametric tests – sign, WilcoXon, Mann-Whitney U-test, Wald Wolfowitz run test, Median test, Kruskal- Wallis test.	1
11.	MS Excel, Applications of computer software to statistical analysis	2
	Total	**16**

I. Course Title : Research Methodology in Forestry

II. Course Code : FOR 610

III. Credit Hours : 3(2+1)

IV. Aim of the course

The students would 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/ field data. The students would also 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 presemntation of results.

V. Theory

Unit I

Experimental Design: Research problem. Types of Research. Need for designing of experiments, Basic principles of design of experiment. Uniformity trials, size and shape of plots and blocks; Analysis of variance, Completely Randomized Design, Randomized Block Design and Latin Square Design. Factorial experiments, (symmetrical as well as asymmetrical). Confounding in symmetrical factorial experiments, Factorial experiments with control treatment. Split plot and strip plot designs; Analysis of covariance and missing plot techniques. Balanced incomplete block design, Fitting of response surfaces. Transformations of data. Groups of experiments.

Unit II

Sampling Theory: Basic terms used in sampling. Simple random sampling, Stratified random sampling, Systematic random sampling. Elementary idea of probability proportional to size, multistage, cluster and inverse sampling.

Unit III

Elementary idea to multivariate analytical tools- Classification and Discriminant function. Factor analysis, Principal component and cluster analysis.

VI Practical

- 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; Fitting of response surfaces. Balanced incomplete block design;
- Groups of experiments. Simple random sampling, Stratified random sampling, Systematic random sampling.

VII. Suggested Reading

- Aggarwal BL. 2011. Theory and Analysis of Experimental Designs. CBS Publisher, New Delhi.
- Gomez KA and Gomez AA. 1984. Statistical Procedure for Agricultural Research. John Wiley and Sons.
- Johnson Richard A and Dean W Wichern. 2015. Applied Multivariate Statistical Analysis. Prentice Hall of India.
- Mukopadhyay Parimal. 2008. Theory and Methods of Survey Sampling. Prentice Hall of India.
- Sahu PK and Das AK.2014. Agriculture and Applied Statistics 2. Kalyani Publisher.
- Singh D and Chaudhary FS. 2018. Theory and Analysis of Sample Survey Design. New Age International Ltd.
- Zar Jerrold H. 2010. Biostatistical Analysis. Prentice Hall.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Need for designing of experiments, Basic principles of design of experiment. Uniformity trials, size and shape of plots and blocks	3
2.	Analysis of variance, Completely Randomized Design, Randomized Block Design and Latin Square Design	4
3.	Factorial experiments, Confounding in symmetrical factorial experiments	4
4.	Factorial experiments with control treatment	1
5.	Split plot and strip plot designs	3
6.	Analysis of covariance and missing plot techniques	2
7.	Balanced incomplete block design, Fitting of response surfaces. Transformations of dat	3
8.	Groups of experiments	2
9.	Basic terms used in sampling. Simple random sampling	3
10.	Stratified random sampling, Systematic random sampling	3
11.	Elementary idea of multistage, cluster and inverse sampling	2
12.	Elementary idea to multivariate analytical tools- Classification and Discriminant function. Factor analysis, Principal component and cluster analysis	2
	Total	**32**
	Practical	
1.	Analysis of variance, Completely Randomized Design, Randomized	

	Block Design and Latin Square Design	3
2.	Factorial experiments, Confounding in symmetrical factorial experiments 3	
3.	Factorial experiments with control treatment	1
4.	Split plot and strip plot designs	2
5.	Analysis of covariance and missing plot techniques	2
6.	Balanced incomplete block design, Fitting of response surfaces. Transformations of data	
7.	Groups of experiments	1
8.	Simple random sampling, Stratified random sampling, Systematic random sampling	2
	Total	**16**

FOR 611 RESEARCH AND PUBLICATION ETHICS 1+1

Theory	
1	Introduction to philosophy: definition, nature and scope, concept, branches
2	Ethics: definition, moral philosophy, nature of moral judgements and reactions
3	Ethics with respect to science and research, Intellectual honesty and research integrity
4	Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP)
5	Redundant publication: duplicate and overlapping publications, salami slicing
6	Selective reporting and misrepresentation of data
7	Publication ethics: definition, introduction and importance
8	Best practices/standards setting initiative and guidelines: COPE, WAME, etc
9	Conflicts of interest
10	Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, type
11	Violation of publication ethics Data fabrication and falsification, Plagiarism, Multiple submissions of a paper, Redundant publications, Improper author contribution or attribution
12	Identification of publication misconduct, complaints and appeals Predatory publishers and journals
13	Open access publications and initiatives
14	SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies

15	Software tool to identify predatory publicationsybSPPU
16	Journal finder/journal suggestion tools viz. JANE Elsevier, Journal Finder, Springer
Practical	
1	Open access publications and initiatives
2	SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies
3	Software tool to identify predatory publications by SPPU,
4	Journal finder/journal suggestion tools viz. JANE Elsevier Journal Finder, Springer
5	Group Discussions: Subject specific ethical issues
6	Group Discussions: FFP, authorship
7	Group Discussions: Conflicts of interest
8	Complaints and appeals: examples and fraud from India and abroad
9	Use of plagiarism software like Turnitin

References :

- Anon. 2019 Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance, ISBN: 978-81-939482-1-7.
- Beall, J., 2012. Predatory publishers are corrupting open access. Nature, 489(7415), 179-179.
- Bird, A. 2006. Philosophy of Science. Routledge.
- Chaddah, P., 2018. Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN: 978-9387480865.
- Thomas, C.G., 2021. Research methodology and scientific writing. Thrissur: Springer.

Common Courses

Common Courses

Course Title with Credit Load

Course Code	Course Title	Credit Hours
CMC 501	Library and Information Services	1(0+1)
CMC 502	Technical Writing and Communications Skills	1(0+1)
CMC 503	Intellectual Property and its Management in Agriculture	1(1+0)
CMC 504	Basic Concepts in Laboratory Techniques	1(0+1)
CMC 505	Agricultural Research, Research Ethics and Rural	
	Development Programmes1	(1+0)
CC 506	Remote sensing and Digital image processing	1(1+0)
CC-507	Remote sensing, GIS and Global Navigation System	1(1+0)

Course Content

CMC 501: LIBRARY AND INFORMATION SERVICES (0+1)

(To be offered by Library Faculty)

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. Plagiarism; Digital Library; Reference Tools; Research Metrics.

CMC 502: TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

(To be offered by Respective Departments and Agricultural Extension Education)

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). 104

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.

CMC 503: INTELLECTUAL PROPERTY AND ITS MANAGEMENT INAGRICULTURE (1+0)

(To be offered by Genetics & Plant Breeding / Agricultural Economics Faculty)

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

CMC 504: BASIC CONCEPTS IN LABORATORY TECHNIQUES(0+1)

(To be offered by Laboratory oriented departments Viz., Soil Science, Bio chemistry, etc.)

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; Neutralization 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, sand bath, water bath, oil bath; 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.

CMC 505: AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (1+0)

(To be offered by Respective Departments and Agricultural Extension Education)

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 theenvironment; 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.

CC-506 (1+0) Remote Sensing and Digital Image Processing

Objective

Providing the students an opportunity for learning the present status of remote sensing and its application, digital image processing of remote sensed data with the help of available software and its basics

Theory:

Introduction to remote sensing (RS),brief history,advantages of RS, spectral signature, fundamental principle of RS, Stages in Remote sensing, Types of RS, Reflectance characteristics of earth surface features-Vegetation, Water and Soil.Fundamental Steps in Digital Image Processing, Components of an Image Processing System, Sampling and Quantization, Representing Digital Images (Data structure), Some Basic Relationships Between Pixels- Neighbors and Connectivity of pixels in image. Digital data manipulation and analysis; image rectification – Radiometric correction, Atmospheric correction, Geometric correction; image enhancement – Spatial feature manipulation and multi-image manipulation; classification techniques – Supervised classification and unsupervised classification.Applications of Image Processing: Forest cover mapping and monitoring, biodiversity characterization, biomass and carbon mapping, Forest fire risk zonation.

CC-507 (1+0) Remote Sensing, GIS and Global Navigation System

Objective

To expose the students about basic information of GNSS, software based GIS applications and processing technology for practical utility of remote sensing

Theory:

Remote Sensing: Definition of terms, Concepts and types of remote sensing; evolution of remote sensing technology, stages in remote sensing technology, spatial data acquisition, interdisciplinary nature and relation with other disciplines, applications of remote sensing, advantages of RS over conventional methods of survey and inventorying. GIS: Definitions, Basic Concepts, history and evolution, Components, Need, Scope, interdisciplinary relations, applications areas, and overview of GIS. Overview of GPS: Basic concept, system architecture, space segment, user segment, GPS aided Geo-augmented navigation (GAGAN) architecture

Overview of IRNSS:

Basics, NavIC System Architecture, Space Segment, Ground Segment, User Segment, IRNSS Services Carrier Frequencies, Data Structure, System Time, Frame Structure, Navigation Data, Ionosphere Correction Coefficients, TEC Calculation.

ವಿಶ್ವವಿದ್ಯಾಲಯ ಮುಖ್ಯ ಆವರಣ, ಇರುವಕ್ಕಿ
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* Contact for further details *

Office of the Dean (PGS)

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