Ph.D. in Soil Science

Re-Structured syllabus as BSMA recommendations 2021-22

[Applicable w.e.f. Academic Session 2024-2025]

TEERTHANKER MAHAVEER UNIVERSITY
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Program Summary

College Name	Teerthanker Mahaveer College of Agriculture Sciences
Program	Ph. D. in Soil Science
Duration	Three years full time (Six Semesters)
Medium	English
Credits	
Minimum Credits Required for Degree	105

About The Program

Ph.D. in Soil science is the three years programme in a comprehensive field that encompasses the study of soil as a natural resource on the surface of the Earth, including its formation, classification, and mapping, and its physical, chemical, biological, and fertility properties. It is an interdisciplinary subject that integrates concepts from various fields to understand and manage soils effectively.

In this field students will learn conducting original research that contributes new knowledge to the field of soil science and focusing on a specific area such as soil chemistry, soil physics, soil biology, soil fertility, or soil conservation. It is interdisciplinary related with other fields such as agronomy, environmental science, geology, hydrology, and ecology. This field also provides innovative technologies and methods in precision agriculture and their utilizing cutting-edge technologies like GIS, remote sensing, and soil sensors for precise soil management and applying biotechnological advancements system to enhance soil fertility and health.

Pursuing a Ph.D. in Soil Science provides a comprehensive and in-depth understanding of soils and their critical role in sustaining life and ecosystems. It prepares students for leadership roles in academia, research, industry, and policy-making, where they can contribute to solving some of the most pressing challenges related to soil and environmental management.

Program Outcomes (POs)

On completion of the three years Ph.D. in soil science, the students will be-

PO1	Understanding advanced knowledge in Soil Science: The post-graduates will learn about the concept of soil and their origin, formation, classification, chemical, physical and biological properties of soil and its composition. Ability to critically analyze and synthesize advanced topics in soil chemistry, physics, biology, and fertility.
PO2	Soil-Plant-Water Relationships: Post-graduates will understand and manage the interactions between soil, plants, and water to optimize agricultural productivity and sustainability.
PO3	Advance knowledge in soil microorganism: Integrate the knowledge about living organisms within soils, including bacteria, fungi, and other microorganisms, as well as their interactions with plants and the environment. And also understand the nutrient cycling, organic matter decomposition, and soil health.
PO4	Developed the research proficiency in the soil fertility field and understanding the nutrient availability, soil amendments, fertilizers, and their impact on crop yield and quality. And also conduct research on root-soil interactions, nutrient uptake, irrigation management, and water quality.
PO5	Implemented advanced technological and methodologies for soil analysis, monitoring, and management. And also use new tools such as GIS, remote sensing, soil sensors, and laboratory equipment.
PO6	Ethical Conduct and Professionalism: Post-Graduates will adhere to ethical standards and professional conduct in their practice soil science, demonstrating integrity, honesty, and respect for scientific integrity and objectivity
PO7	Global and local relevance: Post-graduates will address soil-related challenges at both global and local scales, contributing to solutions for food security, climate change, and land degradation.
PO8	Innovative and problem solving: Post-graduates will apply innovative thinking and problem-solving skills to develop new approaches and technologies in soil science. Development of novel methodologies, adaptation of existing technologies and creative solutions to soil management challenges.

Program Specific Outcomes (PSOs)

On completion of the three-year Ph.D. in Soil Science, the students will be -

PSO1	Advanced in Soil Chemistry: Post-graduates will expertise in the field of chemical composition, reactions, and processes for nutrient dynamics, contaminant behavior, and chemical amendments to improve soil health and productivity.
PSO2	Soil Genesis and Classification Expertise: Post-graduates will acquire comprehensive knowledge of soil formation, classification mapping and conduct soil surveys for land use planning and management.
PSO3	Expertise in Soil Physics Post-graduates will attain advanced knowledge of the physical properties like soil structure, porosity, water retention, and movement to improve soil management practices and address issues such as erosion and compaction.
PSO4	Proficiency in Soil Conservation and Management: Develop advanced skills in soil conservation strategies, such as erosion control measures, crop rotation, and conservation tillage, to maintain soil health and productivity.

SEMESTER-WISE COURSE STRUCTURE AND EVALUATION SCHEME

Ph.D. in Soil Science

Semester- I

S.No.	Course Code	Category	Title of course	L	P	Credit	Evaluation Scheme	
							Min Qualifying Marks	Max Marks
1	RRMD101*	Supporting Course	Research Methodology	4	0	4	60	100
2	RRMD102*	Supporting Course	Quantitative Methods & Computer Applications	2	0	2	60	100
3	RMGT171*	Supporting Course	Review of Literature**	2	0	2	-	-
4	CPE-RPE101*	Supporting Course	Research & Publication Ethics	2	0	2	60	100
5	PDS240168	Major	Clay Mineralogy	2	2	3	60	100
Total				12	2	13	240	400

- ***University common supporting course work.**
- **** Prepare title and review for gap in research**

Semester- II

S.No.	Course Code	Category	Title of course	L	P	Credit	Min Qualifying Marks	Max Marks
1	PDS240169	Major	Modern concept in soil fertility	2	0	2	60	100
2	PDS240170	Major	Physical chemistry of soil	2	0	2	60	100
3	PDS240171	Major	Soil genesis and micromorphology	2	0	2	60	100
4	PDS240172	Major	Bio-chemistry of soil organic matter	3	0	3	60	100
5	PDS240173	Minor	Soil Conservation and Watershed Management	2	2	3	60	100
6	PDS240174	Minor	Recent trends in crop growth and productivity	2	2	3	60	100
Total				13	04	15	360	600

Semester- III

S.No.	Course Code	Category	Title of course	L	P	Credit	Min Qualifying Marks	Max Marks
1	PDS240175	Major	Seminar	-	-	1	Satisfactory/Non-Satisfactory	
2	PDS240176	Major	Research & Thesis	-	-	15	Satisfactory/Non-Satisfactory	
Total				-	-	16	-	-

Semester- IV

Sl. No.	Course Code	Category Major	Title of course	L	P	Credit	Evaluation Scheme	
							Min Qualifying Marks	Max Marks
1	PDS240175	Major	Seminar	-	-	1	Satisfactory/Non-Satisfactory	
2	PDS240176	Major	Research & Thesis	-	-	20	Satisfactory/Non-Satisfactory	
Total:				**-**	**-**	**21**	-	

Semester-V

Sl. No.	Course Code	Category Major	Title of course	L	P	Credit	Evaluation Scheme	
							Min Qualifying Marks	Max Marks
1	PDS240176	Major	Research & Thesis	-	-	20	Satisfactory/Non-Satisfactory	
Total:				**-**	**-**	**20**	-	

Semester-VI

Sl. No.	Course Code	Category Major	Title of course	L	P	Credit	Evaluation Scheme	
							Min Qualifying Marks	Max Marks
1	PDS240176	Major	Research & Thesis	-	-	20	Satisfactory/Non-Satisfactory	
Total:				**-**	**-**	**20**	-	

Break-up of the Courses

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

			Doctoral Programme
(i)	**Course work**	Major courses	**12**
		Minor courses	**06**
		Supporting courses	**10**
		Seminar	**02**
(ii)	**Thesis Research**		75
Total			**105**

List of Major Courses						
S. No.	**Course Code**	**Title of course**	**L**	**T**	**P**	**Credit**
1	PDS240168	Clay Mineralogy	2	0	1	3
2	PDS240169	Modern concept in soil fertility	2	0	0	2
3	PDS240170	Physical chemistry of soil	2	0	0	2
4	PDS240171	Soil genesis and micromorphology	2	0	0	2
5	PDS240172	Bio-chemistry of soil organic matter	3	0	0	3
6	PDS240175	Seminar	0	0	0	2
7	PDS240176	Thesis Research	0	0	0	75

List of Supporting Courses						
No.	**Course Code**	**Title of course**	**L**	**T**	**P**	**Credit**
1	RRMD101	Research Methodology	4	0	0	4
2	RRMD102	Quantitative Methods & Computer Applications	2	0	0	2
	RMGT171	Review of Literature	2	0	0	2
	CPE-RPE101	Research & Publication Ethics	2	0	0	2

List of Minor Courses						
1	PDS240173	Soil Conservation and Watershed Management	2		2	3
2	PDS240174	Recent trends in crop growth and productivity	2		2	3

SYLLABUS

Ph.D. in Soil Science

Clay Mineralogy

Course Type	Course Code	L T P C
Major	PDS240168	2 0 2 3

Course Outcomes (COs).

On completion of the course the students will be-

CO1	Understanding the fundamentals of crystallography of clay minerals
CO2	Apply the knowledge about silicate clay minerals
CO3	Analyze the Genesis and transformation of clay minerals
CO4	Evaluate the X-ray diffraction analysis

Unit I **(6 Hours)**

Definition and concepts of clays and clay minerals, Fundamentals of crystallography – unit cell, external characteristics of crystals, crystallographic notations, crystal systems.

Unit II **(6 Hours)**

Structures and classification of silicate minerals, basics of phyllosilicates, laws governing structural characteristics of phyllosilicates, Goldschmitdt's laws – Laws I and Law II, Classification of Phyllosilicates.

Unit III **(4 Hours)**

Kaolonite group of minerals, Dioctahedral kaolins and Trioctahedral kaolins.

Unit IV **(6 Hours)**

Smectites; properties of smectites, Reference models of structure, principal types based on Hofmann-Marshal-Hendricks (H-M-H) models, occurrence of smectites, transformation and formation in soils.

Unit V **(4 Hours)**

Micas: occurrence and origin in soils, poly types of micas, structure and formation of Muscovites and illite.

Unit VI **(6 Hours)**

Vermicullites: structure, occurrence in soils, formation, relation between vermiculites and montmorillonite.

Unit VII **(6 Hours)**

Chlorite: occurrence and structure of chlorites, "swelling chlorites", formation of chlorite.

Unit VIII **(6 Hours)**

Non-crystalline clays (amorphous materials), subgroups and chemical composition, morphology and structure, physico-chemical properties, influence of non-crystalline clays on soil properties.

Unit IX **(6 Hours)**

Interstratified clay minerals, occurrence and formation in soils, regularly interstratified and partially random interstratified minerals.

Unit X **(6 Hours)**

Genesis and transformation of clay minerals, Generalized conditions for formation and persistence of common clay-size minerals in soils.

Unit XI **(6 Hours)**

Surface chemistry of clay minerals, clay-organic complexes, nanoclay mineralogy.

Unit XII **(6 Hours)**

Clay minerals in different soil orders, role of clay minerals in soil fertility management.

Practical's

1. Separation of clay for mineralogical study
2. X-ray diffraction analysis of clay
3. Selective dissolution of clay minerals
4. IR, DTA and SEM of clay minerals
5. Identification and quantification of clay minerals
6. Determination of surface charge of clay minerals
7. Potentiometric titration of clay minerals

Suggested Reading

1. Dixon JB and Weed SB (Co-editors). Minerals in Soil Environment.
2. Gieseking JE (Ed). Soil Component, Vol. 2. Inorganic Components.
3. Grim RE. Clay Mineralogy.
4. Mukherjee SK and Biswas TD (Editors). Mineralogy of Soil Clays and Clay Minerals.
5. Read HH. Rutley's Elements of Mineralogy.
6. Wilding LP and Smeck NE. 1983. Pedogenesis and Soil Taxonomy Part II – Soil Orders

Modern Concept in Soil Fertility

Course Type	Course Code	L T P C
Major	PDS240169	2 0 0 2

Course Outcomes (COs).

On completion of the course the students will be-

CO1	Understanding the modern concept of nutrient availability to plant
CO2	Apply the knowledge about mechanistic approach to nutrient supply and uptake by plants
CO3	Analyze the chemistry of nutrient in submerge soil
CO4	Evaluate the techniques of soil fertility evaluation

Unit I **(6 Hours)**

Nutrient availability-concept and relationships, modern concepts of nutrient s availability; soil colloids and nutrient availability; soil amendments and availability maintenance of nutrients, soil solution and plant growth; nutrient response functions and availability indices.

Unit II **(4 Hours)**

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

Unit III **(4 Hours)**

Chemical equilibria (including solid-solution equilbria) involving nutrient ions in soils, particularly in submerged soils; Kinetic studies of nutrients in soils.

Unit IV **(4 Hours)**

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

Unit V **(6 Hours)**

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

Unit VI **(6 Hours)**

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

Unit VII **(6 Hours)**

Carbon– a nutrient central to soil fertility; carbon cycle in nature, stocks, pools and fluxes; greenhouse effect and climate change; carbon sequestration vis-à-vis sustenance of soil quality and crop productivity.

Suggested Reading

1. Barber SA. 1995. Soil Nutrient Bioavailability. John Wiley & Sons.
2. Barker V Allen and Pilbeam David J. 2007. Handbook of Plant Nutrition. CRC / Taylor &
3. Francis.
4. Brady NC and Weil RR. 2002. The Nature and Properties of Soils. 13th Ed. Pearson Educ.
5. Cooke GW. 1979. The Control of Soil Fertility. Crossby Lockwood & Sons.
6. Epstein E. 1987. Mineral Nutrition of Plants - Principles and Perspectives. International
7. Potash Institute, Switzerland.
8. Kabata- Pendias Alina 2001. Trace Elements in Soils and Plants. CRC / Taylor & Francis.
9. Kannaiyan S, Kumar K and Govindarajan K. 2004. Biofertilizers Technology. Scientific Publ.
10. Mortvedt JJ, Shuman LM, Cox FR and Welch RM. (Eds.). 1991. Micronutrients in Agriculture.
11. 2nd Ed. Soil Science Society of America, Madison.
12. Prasad R and Power JF. 1997. Soil Fertility Management for Sustainable Agriculture. CRC
13. Press.
14. Stevenson FJ and Cole MA. 1999. Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulphur,
15. Micronutrients. John Wiley & Sons.
16. Stevenson FJ. (Ed.). 1982. Nitrogen in Agricultural Soils. Soil Science Society of America,
17. Madison.
18. Tisdale SL, Nelson WL, Beaton JD and Havlin JL. 1990. Soil Fertility and Fertilizers. 5th
19. Ed. Macmillan Publ.
20. Wild A. (Ed.). 1988. Russell's Soil Conditions and Plant Growth. 11th Ed. Longman.

Physical Chemistry of Soil

Course Type	Course Code	L T P C
Major	PDS240170	2 0 0 2

Course Outcomes (COs).

On completion of the course the students will be-

CO1	Understanding the colloidal chemistry of organic and inorganic components
CO2	Apply the knowledge about thermodynamics of nutrient transformations
CO3	Analyze the adsorption and desorption theory
CO4	Evaluate the electrochemical properties of clays

Unit I **(4 Hours)**

Colloidal chemistry of in organic and organic components of soils–their formation, clay organic interaction.

Unit II **(6 Hours)**

Predictive approaches for cation exchange equilibria- thermodynamics, empirical standing the processes involved with practical significance and diffuse double layer theory (DDL)-relationships among different selectivity coefficients; structure and properties of diffuse double layer.

Unit III **(6 Hours)**

Thermodynamics of nutrient transformations in soils; Climate change effects on mineralogy and surface properties of variable charge; cationic and anionic exchange and their models, molecular interaction.

Unit IV **(6 Hours)**

Adsorption/desorption isotherms-Langmuir adsorption isotherm, Freundlich adsorption isotherm, normalized exchange isotherm, BET equation; selective and non-selective adsorption of ions on in organic surfaces and organic surfaces of soil materials (citation of utility in agricultural system).

Unit V **(6 Hours)**

Common solubility equilibrium-carbonates, iron oxide and hydroxides, aluminum silicate, aluminum phosphate; electrochemical properties of clays (citation of examples from agricultural use).

Suggested Reading

1. Bear RE. 1964. Chemistry of the Soil. Oxford & IBH.
2. Bolt GH and Bruggenwert MGM. 1978. Soil Chemistry. Elsevier.
3. Fried M and Broeshart H. 1967. Soil Plant System in Relation to Inorganic Nutrition. Academic Press.
4. Greenland DJ and Hayes MHB. 1981. Chemistry of Soil Processes. John Wiley & Sons.
5. Greenland DJ and Hayes MHB. 1978. Chemistry of Soil Constituents. John Wiley & Sons.
6. Jurinak JJ. 1978. Chemistry of Aquatic Systems. Department of Soil Science and
7. Biometeorology, Utah State University
8. McBride MB. 1994. Environmental Chemistry of Soils. Oxford University Press.
9. Sparks DL. 1999. Soil Physical Chemistry. 2nd Ed. CRC Press.
10. Sposito G. 1981. The Thermodynamics of Soil Solutions. Oxford University Press.
11. Sposito G. 1984. The Surface Chemistry of Soils. Oxford University Press.
12. Sposito G. 1989. The Chemistry of Soils. Oxford University Press.
13. Stevenson FJ. 1994. Humus Chemistry. 2nd Ed. John Wiley.
14. van Olphan H. 1977. Introduction to Clay Colloid Chemistry. John Wiley & Sons

Soil Genesis and Micromorphology

Course Type	Course Code	L T P C
Major	PDS240171	2 0 0 2

Course Outcomes (COs).

On completion of the course the students will be-

CO1	Understanding the weathering of rocks and mineral and their formation
CO2	Apply the knowledge about soil profile development
CO3	Analyze the Micro-pedological features of soils
CO4	Evaluate the weathering stability and chemical analysis of soil profile

Unit I **(4 Hours)**

Pedogenic evolution of soils; soil composition and characterization.

Unit II **(4 Hours)**

Weathering and soil formation–factors and pedogenic processes; stability and weathering sequences of minerals.

Unit III **(4 Hours)**

Assessment of soil profile development by mineralogical and chemical analysis.

Unit IV **(4 Hours)**

Micro-pedological features of soils–their structure, fabric analysis, role in genesis and classification.

Suggested Reading

1. Brady NC and Weil RR. 2002. The Nature and Properties of Soils. 13th Ed. Pearson Edu.
2. Buol EW, Hole ED, MacCracken RJ & Southard RJ. 1997. Soil Genesis and Classification. 4th Ed. Panima Publ.
3. Dixon JB and Weed SB. 1989. Minerals in Soil Environments. 2nd Ed. Soil Science Society of America, Madison.
4. Grim RE. 1968. Clay Mineralogy. McGraw Hill.
5. Indian Society of Soil Science 2002. Fundamentals of Soil Science. ISSS, New Delhi.
6. Sehgal J. 2002. Introductory Pedology: Concepts and Applications. New Delhi
7. Sehgal J. 2002. Pedology - Concepts and Applications. Kalyani.
8. USDA. 1999. Soil Taxonomy. Hand Book No. 436. 2nd Ed. USDA NRCS, Washington.

Biochemistry of Soil Organic Matter

Course Type	Course Code	L T P C
Major	PDS240172	2 0 0 2

Course Outcomes (COs).

On completion of the course the students will be-

CO1	Understanding the role of organic matter and humus in soil productivity
CO2	Apply the knowledge about biochemistry of the humus formation
CO3	Analyze the Nutrient transformation
CO4	Evaluate the Humus-pesticide interactions in soil, mechanisms.

Unit I **(6 Hours)**

Organic matter in soils and its maintenance Role of organic matter in soil productivity; humus levels in soils; current thinking on the maintenance of organic matter in the soils. Carbon retention and sequestration.

Unit II **(4 Hours)**

Biochemistry of the humus formation; different pathways for humus synthesis in soil; soil carbohydrates and lipids.

Unit III **(4 Hours)**

Nutrient transformation–N, P, S; trace metal interaction with humic substances, significance of chelation reactions in soils.

Unit IV **(6 Hours)**

Reactive functional groups of humic substances, adsorption of organic compounds by clay and role of organic substances in pedogenic soil aggregation processes; clay organic matter complexes.

Unit V **(4 Hours)**

Humus-pesticide interactions in soil, mechanisms.

Reading Materials

1. Lynch JM, Willey JM. Soil Biotechnology.
2. Paul EA and Clark FE. Soil Microbiology and Biochemistry
3. Sherwood LM and Woolverton CJ. Prescott's Microbiology.
4. Subba Rao NS. Advances In Agricultural Microbiology

Soil Conservation and Watershed Management

Course Type	Course Code	L T P C
Major	PDS240173	2 0 2 3

Course Outcomes (COs).

On completion of the course the students will be-

CO1	Understanding the fundamentals of soil erosion and conservation
CO2	Apply the knowledge for development of cropping systems for watershed areas
CO3	Analyze the growth analysis of crops
CO4	Evaluate the productivity trend in irrigated and un-irrigated areas

Unit I **(4 Hours)**

Soil erosion: definition, nature and extent of erosion; types of erosion, factors affecting erosion.

Unit II **(6 Hours)**

Soil conservation: definition, methods of soil conservation; agronomic measures - contour cultivation, strip cropping, cover crops; mulching, tillage, cropping system vegetative barriers; improved dry farming practices; mechanical measures - bunding, gully control, bench terracing; role of grasses and pastures in soil conservation; wind breaks and shelter belts.

Unit III **(6 Hours)**

Watershed management: definition, objectives, concepts, approach, components, steps in implementation of watershed; development of cropping systems for watershed areas.

Unit IV **(6 Hours)**

Land use capability classification, alternate land use systems; agro-forestry; ley farming; jhum management - basic concepts, socio-ethnic aspects, its layout.

Unit V **(6 Hours)**

Drainage, methods of drainage, Drainage considerations and agronomic management; rehabilitation of abandoned jhum lands and measures to prevent soil erosion.

Practical:

1. Study of different types of erosion
2. Determination of dispersion ratio
3. Estimation of soil loss by Universal Soil Loss Equation
4. Estimation of soil loss by wind erosion

5. Measurement of runoff and soil loss
6. Field studies of different soil conservation measures
7. Laying out run-off plot and deciding treatments
8. Identification of different grasses and trees for soil conservation
9. Visit to watershed areas
10. Visit to a soil conservation research centre, demonstration and training centre

Suggested Reading:

Arakeri HR and Roy D. 1984. Principles of Soil Conservation and Water Management. Oxford & IBH. • Dhruvanarayana VV. 1993. Soil and Water Conservation Research in India. ICAR. • FAO. 2004. Soil and Water Conservation in Semi-Arid Areas. Soils Bull., Paper 57. • Frederick RT, Hobbs J, Arthur D and Roy L. 1999. Soil and Water Conservation: Productivity and Environment Protection. 3rd Ed. Prentice Hall.

Recent Trends in Crop Growth and Productivity

Course Type	**Course Code**	**L T P C**
Major	PDS240174	2 0 2 3

Course Outcomes (COs).

On completion of the course the students will be-

CO1	Understanding the fundamentals crop growth and their productivity
CO2	Apply the knowledge about maximizing solar energy utilization in crop growth
CO3	Analyze the growth analysis of crops
CO4	Evaluate the productivity trend in irrigated and un-irrigated areas

Unit I **(6 Hours)**

Plant density and crop productivity; plant and environmental factors, yield, plant distribution, strategies for maximizing solar energy utilization; leaf area; interception of solar radiation and crop growth; photosynthesis: the photosynthetic apparatus, factors essential for photosynthesis; difference in photosynthetic rates among and within species; physiological limitations to crop yield; solar radiation concept and agro-techniques for harvesting solar radiation.

Unit II **(6 Hours)**

Growth analysis: concept, CGR, RGR, NAR, LAI, LAD, LAR; validity and Limitations in interpreting crop growth and development; growth curves: sigmoid, polynomial and asymptotic; root systems; root-shoot relationship; principles involved in inter and mixed cropping systems under rainfed and irrigated conditions; concept and differentiation of inter and mixed cropping; criteria in assessing the yield advantages.

Unit III **(6 Hours)**

Competitive relationship and competition functions; biological and agronomic basis of yield advantage under intercropping; physiological principles of dry land crop production, constraints and remedial measures; heat unit concept of crop maturity: concept and types of heat units.

Unit IV **(6 Hours)**

Concept of plant ideotypes: crop physiological and new ideotypes; characteristics of ideotype for wheat, rice, maize, etc.; concept and types of growth hormones; their role in field crop production; efficient use of resources.

Practical

1. Field measurement of root-shoot relationship in crops at different growth stages
2. Estimation of growth evaluating parameters like CGR, RGR, NAR, LAI etc., at Physical Sciences: Agronomy 67 different stages of crop growth
3. Computation of harvest index of various crops
4. Assessment of crop yield on the basis of yield attributing characters
5. Construction of crop growth curves based on growth analysis data
6. Computation of competition functions, viz. LER, IER aggressivity competition index etc in intercropping • Senescence and abscission indices
7. Analysis of productivity trend in un-irrigated areas
8. Analysis of productivity trend in irrigated areas

Suggested Reading

1. Chopra VL and Paroda RS. 1984. Approaches for Incorporation of Drought and Salinity Resistance in Crop Plants. Oxford & IBH.
2. Delvin RM and Vitham FH. 1986. Plant Physiology. CBS Publ.
3. Evans LT. 1975. Crop Physiology. Cambridge Univ. Press.
4. Evans LT. 1996. Crop Evolution, Adaptation and Yield. Cambridge Univ. Press.

5. Gupta US. (Ed.). 1995. Production and Improvement of Crops for Drylands. Oxford & IBH.
6. Gupta US. 1988. Progress in Crop Physiology. Oxford & IBH.
7. Kramer PJ and Boyer JS. 1995. Water Relations of Plant and Soils. Academic Press.
8. Mukherjee S and Ghosh AK. 1996. Plant Physiology. Tata McGraw Hill.
9. Narwal SS, Politycka B and Goswami CL. 2007. Plant Physiology: Research Methods. Scientific Pub. • Tiaz L. and Zeiger E. 2006. Plant Physiology. Sinauer Associates, Inc.

Research Methodology
COURSE CODE: RRMD101

1. Scientific Research: meaning and characteristics of scientific research, validity in research, phases/stages in research; types of research- qualitative, quantitative, exponential, exploratory, empirical, descriptive, ex-post facto, case studies, historical studies, philosophical studies, quasi-experimental; ethical problems in research; constructs and variables- nature of construct and variables, concept of constructs, type of variables, continuous and categorical, constructs, observables and intervening variables; Review of literature- purpose of the review, sources of the review, preparation of index card for reviewing and abstracting.
2. Problem Identification and Hypothesis Formation: problem- meaning and characteristics of a problem, types of problem, generality and specific of problem; hypothesis- meaning and characteristics of a good hypothesis, types of hypotheses, formulating a hypothesis, ways of stating a hypothesis; testing experimental hypothesis- standard error, test of significance, level of significance, degrees of freedom, errors in hypothesis- type I, type II errors.
3. Sampling and Research Design: meaning and types of sampling; probability and non probability sampling. methods of drawing samples, requisites of a good sampling method, sample size, sampling error; meaning and purpose of research design, types of research design, criteria of a good research design, basic principles of experimental design.
4. Introduction to MS-Office: MS-WORD, MS-EXCEL, MATLAB, LATEX.

Suggested Reading:

1. Cooper & Schindler, *Business Research Methods*, Tata McGraw Hill.
2. Saunders, *Research Methods for Business Students*, Pearson Education
3. Allen T Harrell, *New Methods in Social Science Researchs*, Praeger Publishers, New York
4. Beri, G.C., S*tatistics for Management*, Tata MacGraw-Hill
5. Chandan J. S., *Statistics for Business and Economics*, Vikas Publications.

6. Broota, K.D., *Experimantal Designs in Behavioural Research*, New Age International
7. Singh A. K., *Test Measurement and Research Methods in Behaviours Sciences*, Bharti Bhawan
8. Joyce Cox & Polly Urban, *Microsoft Office*, Galgotia Publishing
9. Sinha P.K., *Computer Fundamentals*, BPB Publishing.

Quantitative Methods and Computer Applications (RRMD102)

1. Measurement and Scaling Techniques: measurement in research, measurement scales sources of errors in measurement, tests of second measurement, techniques of developing measurement tools, meaning of scaling, scale classification bases, important scaling techniques, and scale construction techniques.
2. Data Collection, Processing and Analysis: methods of data collection – primary data, secondary data; primary data collection – observation method, interview method, questionnaires, schedules, guideline for constructing questionnaires/schedules, secondary data collection of, selection of appropriate method of data collection; coding, editing and tabulation of data, charts and diagrams used in data analysis, bar and pie diagrams and their significance; measures of central tendency, measures of dispersion; correlation and regression analysis - meaning and uses, methods of calculation of coefficients and their analysis and implication. sampling distribution, sampling schemes and sample sizes, confidence interval for the mean, t-statistic, z-statistic, confidence interval for the population variances, hypothesis testing, test of hypothesis for the population mean, population variance and ratio of two population variances; applications of z-test, t-test, f-test and chi-square test, association of attributes and techniques of testing, ANOVA.
3. Report Writing: meaning and significance of report writing, types of report, steps in writing report, layout of the research report, precaution in writing research report, developing thesis report, formatting, inside citations, references and bibliography, knowledge of computer, statistical software and their application, application of statistical tests/techniques through the use of statistical software like SPSS, scientific packages like LISREL, AMOS, and SYSTAT for documentation and report generation.

Suggested Reading:

1. Cooper & Schindler, *Business Research Methods*, Tata McGraw Hill.
2. Malhotra Naresh K., *Marketing Research*, Pearson Education
3. Power Analysis for experimental Research: A practical Guide for the Biological, Medical and Social Sciences by R. Barker Baushell, Yu-Fang Li Cambridge University Press
4. Chandan J. S., *Statistics for Business and Economics*, Vikas Publications.
5. Broota, K.D., *Experimantal Designs in Behavioural Research*, New Age International
6. Singh A. K., *Test Measurement and Research Methods in Behaviours Sciences*, Bharti Bhawan

7. Joyce Cox & Polly Urban, *Microsoft Office*, Galgotia Publishing
8. Sinha P.K., *Computer Fundamentals*, BPB Publishing.
9. Latex: A Document Preparation System, 2/E pearson low price edition by Lamport
10. MATLAB: An Introduction with Applications by Gilat Wiley India Pvt. Ltd.
11. Getting started with MATLAB by Rudra Pratap Oxford University Press.

EVALUATION OF REVIEW OF LITERATURE (RMGT171)

The research scholar will review the important studies conducted at the national and international level either by individuals or organizations including government agencies and present the methodology adopted and important findings emerged from these studies. Based on this review of literature the researcher will identify the research gaps existing in the available literature and thus justifying the need for the present study.

The researcher is supposed to follow the pattern adopted in the standard national and international research journals. However, as an illustration the pattern for reporting review of literature is as under:

1. Tiwari and Sinha (1971) gave productivity trends and factor compensation in Indian textiles industry for the period 1946-65 comprising of two sub-periods (1946- 1955 and 1956-1965). The marginal productivity of capital on an average for the industry as a whole is found to be lower in the sub-period (1946-55) and higher during (1956- 65). On the contrary, the estimates of the marginal productivity of labour again on average exhibit an actual decline from 2.9 percent to 2.5 percent.
2. Menon (1971) in his review article examines the concepts associated with measurement of productivity at various dimensions of output and input, which are the major elements involved in the exercise of measuring productivity.
3. Kumar, Anil and Khurana (2007) in their paper have examined trends in productivity of labour and capital in dairy industry in India during pre and post-reform periods. The results in the study conclude that labour productivity at national level has shown considerable improvement during post-reform period. But variations have been observed in case of growth rate of labour productivity at state-level. On the other hand, capital productivity has declined during post-reform period at national and state levels.
4. Kumar and Bala (2007) in their study on "An evaluation of the impact of economic reforms on the growth and productivity of Indian small scale sector" has concluded that economic reforms process initiated in the early nineties has had a downbeat impact on the growth and productivity of small scale sector.

Research & Publication Ethics (CPE-RPE101)

Theory

- **RPE 01: PHILOSOPHY AND ETHICS (3 hrs.)**
    1. Introduction to philosophy: definition, nature and scope, concept, branches
    2. Ethics: definition, moral philosophy, nature of moral judgments and reactions
- **RPE 02: SCIENTIFIC CONDUCT (5 hrs.)**
    1. Ethics with respect to science and research
    2. Intellectual honesty and research integrity
    3. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP)
    4. Redundant publications: duplicate and overlapping publications, salami slicing
    5. Selective reporting and misrepresentation of data
- **RPE 03: PUBLICATION ETHICS (7 hrs.)**
    1. Publication ethics: definition, introduction and importance
    2. Best practices / standards setting initiatives and guidelines: COPE, WAME, etc.
    3. Conflicts of interest
    4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types
    5. Violation of publication ethics, authorship and contributorship
    6. Identification of publication misconduct, complaints and appeals
    7. Predatory publishers and journals

Practice

- **RPE 04: OPEN ACCESS PUBLISHING (4 hrs.)**
    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 developed by SPPU
    4. Journal finder/journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggested, etc.
- **RPE 05: PUBLICATION MISCONDUCT (4hrs.)**

Group Discussions (2 hrs.)

1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

Software tools (2 hrs.)

Use of plagiarism software like Tumitin, Urkund and other open source software tools

- **RPE 06: DATABASES AND RESEARCH METRICS (7hrs.)**

. Databases (4 hrs.)

1. Indexing databases
2. Citation databases: Web of Science, Scopus, etc.

Research Metrics (3 hrs.)

3. Impact Factor of journal as per Journal Citation Report, SNIP, SIR, IPP, Cite Score
4. Metrics: h-index, g index, i10 index, altmetrics