SCHOOL OF AGRICULTURE

Ph.D. in Soil Science

Course structure

Course Code	**Course Title**	**Credit Hours**
Soil 601	Recent Trends in Soil Physics	2+0
Soil 602	Modern Concept in Soil Fertility	2+0
Soil 603*	Physical Chemistry of Soil	2+0
Soil 604*	Soil Genesis and Micromorphology	2+0
Soil 605	Bio-chemistry of Soil Organic Matter	2+0
Soil 606	Soil Resource Management	3+0
Soil 607	Modelling of Soil Plant System	2+0
Soil 608	Clay Mineralogy	2+1
Soil 609	Recent Trends in Soil Microbial Biodiversity	2+1
Soil 691	Doctoral Seminar I	1+0
Soil 692	Doctoral Seminar II	1+0
Soil 699	Doctoral Research	75
	Minor Courses	06
	Supporting courses	05

** Indicates Core Courses which are Compulsory for Ph.D. Programme.*

DETAILED SYLLABUS

Course Title : Recent Trends in Soil Physics

Course Code : Soil 601

Credit Hours : (2+0)

Aim of the course

To provide knowledge of modern concept sin soil physics.

Theory

Block 1: Soil-water relations and flow

Unit I:

Soil-water interactions, soil water potential, free energy and thermodynamic basis of potential concept, chemical potential of soil water and entropy of the system, soil-plant-atmospheric continuum (SPAC).

Unit II:

Fundamentals of fluid flow, Poiseuilles law, Laplace's equation, Darcy's law in saturated and unsaturated flows; development of differential equations in saturated and unsaturated waterflow, capillary conductivity and diffusivity; limitations of Darcy's law; numerical solution for one dimensional waterflow.

Block 2: Infiltration and solute transport

Unit III:

Theories of horizontal and vertical infiltration under different boundary conditions.

Unit IV:

Movement of salts in soils, models formiscible-immiscible displacement, diffusion, mass flow and dispersion of solutes and their solutions through differential equations; break-through curves.

Block 3: Soil air, heat, plant-water relations and soil management

Unit V:

Soil air and aeration, mass flow and diffusion processes; thermal properties of soil, heat transfer in soils, differential equation of heatflow, measurement of thermal conductivity of soil; Soil, Plant, Water relations- Plant uptake of soil moisture, Water balance and energy balance in the field; irrigation and water use efficiency.

Unit VI:

Soil crust and clod formation; structural management of puddled rice soils; soil conditioning-concept, soils conditioners-types, characteristics, working principles, significance in agriculture.

Unit VII:

Solar and terrestrial radiation measurement, dissipation and distribution in soil- crop systems; prediction of evapotranspiration using aerodynamic and canopy temperature-based models; canopy temperature and leaf diffusion resistance in relation to plant water deficit; evaluation of soil and plant water status using infra-red thermometer. 101 Restructured and Revised Syllabi of Post-graduate Programmes Vol. 2

Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

Suggested Reading

- Baver LD, Gardner WH and Gardner WR. 1972. Soil Physics. John Wiley & Sons.
- Hanks and Ascheroft. 1980. Applied Soil Physics. Springer Verlag.
- Hillel D. 1980. Applications of Soil Physics. Academic Press.
- Hillel D. 1980. Environmental Soil Physics. Academic Press.
- Indian Society of Soil Science 2002. Fundamentals of Soil Science. ISSS, New Delhi.
- Kirkham D and Powers WL. 1972. Advanced Soil Physics. Wiley Interscience.
- Lal R and Shukla MK. 2004. Principles of Soil Physics. Marcel Dekker.
- Oswal MC. 1994. Soil Physics. Oxford & IBH.

Course Title : Modern Concept in Soil Fertility

Course Code : Soil 602

Credit Hours : (2+0)

Aim of the course

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

Theory

Block 1: Nutrient availability, movement and equilibria

Unit I:

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:

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

Unit III:

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

Block 2: Fertilizer evaluation, application and nutrient-use efficiency

Unit IV:

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

Unit V:

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

Block 3: Long-term soil fertility and carbon dynamics

Unit VI:

Monitoring physical, chemical and biological changes in soils; permanent manurial 102 Physical Sciences: Soil Science trials and long-term fertilizer experiments; soil productivity under long-term intensive cropping; direct, residual and cumulative effect of fertilizer use.

Unit VII:

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.

Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on the knowledge of soil fertility and fertilizers in relation to plant growth and development.

Suggested Reading

- Barber SA. 1995. Soil Nutrient Bioavailability. John Wiley & Sons.
- Barker V Allen and Pilbeam David J. 2007. Handbook of Plant Nutrition. CRC / Taylor & Francis.
- Brady NC and Weil RR. 2002. The Nature and Properties of Soils. 13th Ed. Pearson Educ.
- Cooke GW. 1979. The Control of Soil Fertility. Crossby Lockwood & Sons.
- Epstein E. 1987. Mineral Nutrition of Plants - Principles and Perspectives. International Potash Institute, Switzerland.
- Kabata- Pendias Alina 2001. Trace Elements in Soils and Plants. CRC / Taylor & Francis.

- Kannaiyan S, Kumar K and Govindarajan K. 2004. Biofertilizers Technology. Scientific Publ.
- Mortvedt JJ, Shuman LM, Cox FR and Welch RM. (Eds.). 1991. Micronutrients in Agriculture. 2nd Ed. Soil Science Society of America, Madison.
- Prasad R and Power JF. 1997. Soil Fertility Management for Sustainable Agriculture. CRC Press.
- Stevenson FJ and Cole MA. 1999. Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulphur, Micronutrients. John Wiley & Sons.
- Stevenson FJ. (Ed.). 1982. Nitrogen in Agricultural Soils. Soil Science Society of America, Madison.
- Tisdale SL, Nelson WL, Beaton JD and Havlin JL. 1990. Soil Fertility and Fertilizers. 5th Ed. Macmillan Publ.
- Wild A. (Ed.). 1988. Russell's Soil Conditions and Plant Growth. 11th Ed. Longman.

Course Title : Physical Chemistry of Soil

Course Code : Soil 603

Credit Hours : (2+0)

Aim of the course

To impart knowledge about modern concepts of physical chemistry of soils and clays, with emphasis on understanding the processes involved with practical significance.

Theory

Block 1: Soil colloids and cation-exchange equilibria

Unit I:

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

Unit II:

Predictive approaches for cation exchange equilibria- thermodynamics, empirical 103 Restructured and Revised Syllabi of Post-graduate Programmes Vol. 2 and diffuse double layer theory (DDL)- relationships among different selectivity coefficients; structure and properties of diffuse double layer.

Block 2: Nutrient transformations, adsorption and solubility equilibria

Unit III:

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

Unit IV:

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:

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

Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on the knowledge of soil chemical behaviour on research for solving field problems.

Suggested Reading

- Bear RE. 1964. Chemistry of the Soil. Oxford & IBH.
- Bolt GH and Bruggenwert MGM. 1978. Soil Chemistry. Elsevier.
- Fried M and Broeshart H. 1967. Soil Plant System in Relation to Inorganic Nutrition. Academic Press.
- Greenland DJ and Hayes MHB. 1981. Chemistry of Soil Processes. John Wiley & Sons.
- Greenland DJ and Hayes MHB. 1978. Chemistry of Soil Constituents. John Wiley & Sons.
- Jurinak JJ. 1978. Chemistry of Aquatic Systems. Department of Soil Science and Biometeorology, Utah State University
- McBride MB. 1994. Environmental Chemistry of Soils. Oxford University Press.
- Sparks DL. 1999. Soil Physical Chemistry. 2nd Ed. CRC Press.
- Sposito G. 1981. The Thermodynamics of Soil Solutions. Oxford University Press.

Course Title : Soil Genesis and Micromorphology

Course Code : Soil 604

Credit Hours : (2+0)

Aim of the course

To impart knowledge about the pedogenic processes in soils and to acquaint with the micro-pedological study of soil profile.

Theory

Block 1: Pedogenic evolution, weathering and soil formation

Unit I:

Pedogenic evolution of soils; soil composition and characterization. 104 Physical Sciences: Soil Science

Unit II:

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

Block 2: Soil profile development and micromorphology

Unit III:

Assessment of soil profile development by mineralogical and chemical analysis.

Unit IV:

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

Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on the knowledge of soil micro pedology and soil taxonomy on research for solving field problems.

Suggested Reading

- Brady NC and Weil RR. 2002. The Nature and Properties of Soils. 13th Ed. Pearson Edu.
- Buol EW, Hole ED, MacCracken RJ & Southard RJ. 1997. Soil Genesis and Classification. 4th Ed. Panima Publ.
- Dixon JB and Weed SB. 1989. Minerals in Soil Environments. 2nd Ed. Soil Science Society of America, Madison.
- Grim RE. 1968. Clay Mineralogy. McGraw Hill.
- Indian Society of Soil Science 2002. Fundamentals of Soil Science. ISSS, New Delhi.
- Sehgal J. 2002. Introductory Pedology: Concepts and Applications. New Delhi
- Sehgal J. 2002. Pedology - Concepts and Applications. Kalyani.
- USDA. 1999. Soil Taxonomy. Hand Book No. 436. 2nd Ed. USDA NRCS, Washington.
- Wade FA and Mattox RB. 1960. Elements of Crystallography and Mineralogy. Oxford & IBH.

Course Title : Biochemistry of Soil Organic Matter

Course Code : Soil 605

Credit Hours : (2+0)

Aim of the course

To impart knowledge related to chemistry and reactions of organic substances and their significance in soils.

Theory

Block 1: Soil organic matter and humus formation

Unit I:

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:

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

Block 2: Nutrient transformations and interactions of humic substances

Unit III:

Nutrient transformation–N, P, S; tracemetal interaction with humic substances, significance of chelation reactions in soils. 105 Restructured and Revised Syllabi of Post-graduate Programmes Vol. 2

Unit IV:

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:

Humus-pesticide interactions in soil, mechanisms.

Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on the knowledge of soil biochemistry on research for solving field problems.

Suggested Reading

- Lynch JM, Willey JM. Soil Biotechnology.
- Paul EA and Clark FE. Soil Microbiology and Biochemistry

- Sherwood LM and Woolverton CJ. Prescott's Microbiology.
- Subba Rao NS. Advances In Agricultural Microbiology

Course Title : Soil Resource Management

Course Code : Soil 606

Credit Hours : (3+0)

Aim of the Course:

To impart the students basic holistic knowledge on soil resource and latest developments in its sustainable use.

Theory

Block 1: Soil Resources and Sustainable Land Management

Unit I

Relevance of soil management to sustainable agriculture; soil as a natural resource for biomass production, filtering, buffering, transportation of solutes, gene reserves, and geogenic source of raw materials; soil as a source and sink of greenhouse gases.

Unit II

Concept of sustainable land management (SLM); spatial variability of soils; soil quality and food security; soil quality indices, conservation agriculture in relation to soil quality; soil resilience and resistance.

Block 2: Land Degradation, Soil Erosion and Conservation

Unit III

Types, factors and causes of land degradation and desertification; GLASOD classification; application of GIS and remote sensing in monitoring, diagnosis and mapping land degradation; history, distribution, identification and description of soil erosion problems in India; forms of soil erosion; impact of soil erosion—on-site and off-site effects; strategies for erosion control and conservation; soil conservation in hilly, arid, semi-arid, coastal and diara lands; management of forest, peat and muck soils.

Unit IV

Soil conservation planning; land capability classification; soil conservation in special problem areas such as hilly, arid and semi-arid regions, waterlogged areas and wetlands; land restoration and conservation techniques—erosion control, reclamation of salt-affected soils, mine land reclamation, afforestation, organic products, soil fauna and biodegradation.

Block 3: Watershed Management and Land Evaluation

Unit V

Watershed management—concept, objectives and approach; water harvesting and recycling; flood control in watershed management; socio-economic aspects of watershed management; case studies in respect to monitoring and evaluation of watersheds.

Unit VI

Agro-ecological regions of India; potentials and constraints of soils of different regions; land evaluation and rationalizing land use; decision support system with relation to land management; national and international soil policy considerations.

Teaching Methods/Activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning Outcome

Experience on the knowledge of soil resources on research for solving field problems.

Suggested Reading

•Abrol IP and Dhruvanarayana VV. 1990. *Technology for Wasteland Development*. ICAR, New Delhi.

•Andriesse JP. 1988. *Nature and Management of Tropical Peat Soils*. FAO Soils Bulletin 59. FAO, Rome.

•Dent D and Young A. 1981. *Soil Survey and Land Evaluation*. George Allen and Unwin, London.

•Burrough A and McDonnell RK. 1998. *Principles of Geographical Information System*. Oxford University Press.

•Binkley D and Fisher R. 2012. *Ecology and Management of Forest Soils*. 4th Edition, Wiley.

•FAO. 1996. *Land Quality Indicators and their Use in Sustainable Agriculture and Rural Development*. FAO, Rome.

Course Title : Modelling of Soil Plant System

Course Code : Soil 607

Credit Hours : (2+0)

Aim of the Course

To train the students in concepts, methodology, technology and use of systems simulation in soil and crop studies.

Theory

Block 1: Modelling Concepts, Numerical Methods and Computing

Unit I: Introduction, terms and definitions; classification of models; Taylor series; numerical methods of differentiation and integration.

Unit II: High-level computer language: FORTRAN—commands and usage; testing and evaluation of models.

Block 2: Soil Process Models and Nutrient Uptake Simulation

Unit III: Spatially homogeneous models; K-transformation model; nitrogen and phosphorus dynamics in soil.

Unit IV: Spatially heterogeneous models; equation of continuity; simulation of water flow through soil; explicit and explicit–implicit methods; simulation of solute movement through soil with variable moisture flux by explicit–implicit method.

Unit V: Nutrient-uptake model integrating nutrient movement in soil by mass flow and diffusion with plant uptake using Michaelis–Menten kinetics; nutrient-uptake model based on solubility and free-ion activity.

Teaching Methods/Activities

Classroom teaching with AV aids, group discussion and oral presentations by students.

Learning Outcome

Experience on soil modelling concepts for forecasting productivity.

Suggested Reading

- Datta SC. 2008. Theory and Principles of Simulation Modeling in Soil-Plant System. Capital Publishing Company, New Delhi.
- Frame J and Thornley JHM. 1984. Mathematical Models in Agriculture—A Quantitative approach to problems in agriculture and related science. Butterworth and Co. Ltd.
- Freud PJ and Minton PD. 1979. Regression Methods—A tool for data Analysis. Marcel Dekker Inc., New York.
- Frissel MJ and Reinger P. 1974. Simulation of Accumulation and Leaching in Sils. Oxford and IBM Pub. Co., New Delhi.
- Hanks J and Richie JT. (Eds.). 1991. Modeling Plant and Soil System. Agronomy Bulletin No. 31, ASA, SSSA Madison, Wisconsin, USA.
- Lipschutz S and Poe A. 1978. Schaum's Outline Series–Theory and Problems of programming with Fortran. McGraw-Hill Book Co., Singapore.
- Penning de Vries FWT, Jansen DM, Ten Berge HFM and Baker A. 1989. Simulation of ecophysiological processes of growth in several annual crops. PUDOC, Wageningen.

Course Title : Clay Mineralogy

Course Code : Soil 608

Credit Hours : (2+1)

Theory

Block 1: Clay concepts, crystallography and kaolinite

Unit I:

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

Unit II:

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:

Kaolonite group of minerals, Dioctahedral kaolins and Trioctahedral kaolins.

Block 2: Layer silicate clay minerals

Unit IV:

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:

Micas: occurrence and origin in soils, polytypes of micas, structure and formation of muscovites and illite.

Unit VI:

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

Unit VII:

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

Block 3: Non-crystalline and interstratified clay minerals

Unit VIII:

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:

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

Block 4: Clay genesis, surface chemistry and agricultural significance

Unit X:

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

Unit XI:

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

Unit XII:

Clay minerals in different soil orders, role of clay minerals in soil fertility management. 109 Restructured and Revised Syllabi of Post-graduate Programmes Vol. 2

Practical

- Separation of clay for mineralogical study
- X-ray diffraction analysis of clay
- Selective dissolution of clay minerals
- IR, DTA and SEM of clay minerals
- Identification and quantification of clay minerals
- Determination of surface charge of clay minerals
- Potentiometric titration of clay minerals.

Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on soil clays and utility in soil research.

Suggested Reading

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

Course Title : Recent Trends in Soil Microbial Biodiversity

Course Code : Soil 609

Credit Hours : (2+1)

Theory

Block 1: Microbial biodiversity, communities and ecology

Unit I:

Microbial evaluation and biodiversity, Microbial communities in ecosystems, New insights in below ground diverse of plant performance.

Unit II:

Qualitative ecology of microorganisms; Biomass and activities.

Block 2: Nitrogen-fixing organisms and molecular characterization

Unit III:

Nitrogen fixing organisms, Trends in diversity of N fixing organisms. Molecular approaches in characterising N fixing microorganisms.

Unit IV:

Serology and molecular characterization, ecological aspects of bio determination, soil waste and water management

Block 3: Biodegradability and bioremediation

Unit V:

Biodegradability, testing and monitoring of the bioremediation of xerobiotic pollutants and bacterial fertilizers.

Practical

- Determination of soil microbes using classical techniques.
- Determination of soil microbial diversity using molecular techniques.
- Estimation of soil microbial biomass carbon, nitrogen and phosphorus.
- Estimation of key soil enzyme activities.
- Community level physiological profiling of microbial diversity. 110 Physical Sciences: Soil Science

Teaching methods/activities

Classroom teaching with AV aids, group discussion, field visit

Learning outcome

Experience on soil microbial diversity and planning for proper utilization.

Suggested Reading

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