COURSE NO : SSAC-353

Course Title : Manures, Fertilizers and Soil Fertility Management

Course Credits : 3 (2+1)

SEMESTER V (New)

Dr. Vikrant P. Bhalerao
(Assistant Professor)

Dept. of Soil Science and Agril. Chemistry

College of Agriculture, Dhule

Course Title : Manures, Fertilizers and Soil Fertility Management **B. Sc. (Agri.)**

Course No. : SSAC- 353 **Semester: V (New)** **Credit : 3 (2+1)**

Teaching Schedule

A. THEORY

Lesson	Topic	Weightage (%)
1 & 2	History of soil fertility and plant nutrition.	3
3 & 4	Soil as a source of plant nutrients, essential and beneficial nutrients and their role. Criteria of essentiality, forms of nutrients in soil.	5
5, & 6	Introduction and importance of organic manures. Sources of organic matter, recycling, composition and C:N ratio.	5
7, 8 & 9	Definition, properties and classification of bulky and concentrated organic manures, their composition and nutrient availability. Preparation of FYM, composts, different methods of composting, decomposition process and nutrient losses during handling and storage.	6
10 & 11	Vermicomposting, green manuring; types, advantages and disadvantages and nutrient availability.	5
12 & 13	Sewage and sludge, Biogas plant slurry; their composition and effect on soil and plant growth.	5
14 & 15	Integrated nutrient management; concept, components and importance.	6
16 & 17	Fertilizer; Definition and their classification; N fertilizers: classification, manufacturing process and properties their fate and reaction in soils.	6
18 & 19	Phosphatic fertilizers, manufacturing process and properties, classification, their fate and reaction in soils.	5
20 & 21	Potassic fertilizers: classification, manufacturing process, properties, their fate and reaction in soils. Complex fertilizers their fate and reaction in the soil. Nano fertilizers.	5
22 & 23	Secondary &micronutrient fertilizers: Types, composition, reaction in soil and effect on crop growth. Soil amendments.	5
24	Handling and storage of fertilizers: Fertilizer control order.	3
25 & 26	Mechanism of nutrient transport to plants: Factors affecting nutrient availability to plants. Measures to overcome deficiencies and toxicities.	6
27,28 & 29,	Chemistry of soil N,P, K, calcium, magnesium, sulphur and micronutrients.	6
30 & 31	Soil fertility evaluation and different approaches.	6
32	Soil Testing (Available nutrients) : Chemical methods and critical levels of different nutrients in soil.	6
33	Plant analysis methods : Critical levels of nutrients, DRIS approach, rapid tissue test, indicator plants. Soil test based fertilizer recommendations to crops.	6
34 & 35	Methods and scheduling of nutrient applications for different soils and crops grown under rain fed and irrigated conditions.	6
36	Factors influencing nutrients use efficiency (NUE) in respect of N, P, K, S, Fe and Zn fertilizers.	5
	Total	100

B. PRACTICALS

Experiment	Topic
1	Principle and application of spectro-photometry / Colorimetry.
2	Principle and application of flame photometry and atomic absorption spectrophotometer (AAS).
3	Determination of moisture from organic manures and its preparation for nutrient analysis.
4	Determination of organic carbon from organic manures by ignition method.
5	Estimation of available nitrogen in soil (Alkaline permanganate method)
6	Estimation of available phosphorus in soil.
7	Determination of available potassium in soil using flame photometer.
8	Determination of exchangeable Ca & Mg in soil by EDTA method.
9	Estimation of available sulphur in soil (Turbidity method).
10	Estimation of DTPA extractable micronutrients from soil using AAS.
11	Estimation of total N from plant sample by Micro Kjeldahl's method.
12	Plant analysis for P, K, secondary and micronutrients.
13	Fertilizer adulteration test / identification of adulteration in fertilizer / Detection of adulteration in fertilizers (Rapid test).
14	Determination of nitrate nitrogen content of potassium nitrate.
15	Determination of water soluble phosphorus in superphosphate (Pumberton method).
16	Determination of acid soluble phosphorus from rock phosphate.
17	Determination of total potassium content of muriate of potash (Flame photometer).
18	Determination of zinc content from micronutrient fertilizer (EDTA Method).

Suggested Readings :

1) Tandon H. L. S. (1994) Recycling of crop, animal, human and industrial Wastes in Agriculture. FDCO, Delhi
2) Krishna and Murthy (1978) Manual on compost and other organic manures .
3) Rakshit A. (2015) Manures Fertilizers and Pesticides Paperback – Import. CBS Publishing; 1ST edition, pp. 266.
4) Zhongqi Heand Hailin Zhang (2016) Applied Manure and Nutrient Chemistry for Sustainable Agriculture and Environment Paperback – Import. Springer. pp. 379.
5) Havlin, John L, Samuel L. Tisdale (Author), Werner L. Nelson (Author), James D. Beaton (2004) Soil Fertility and Fertilizers (8th Edition) 8th Edition. Published July 23rd 2004 by Prentice Hall. pp. 528.
6) Havlin, John L. (2004) Soil Fertility and Fertilizers: An Introduction to Nutrient Management Published July 23rd 2004 by Prentice Hall. pp. 528.

7) James F. Power, Rajendra Prasad (1997) Soil Fertility Management for Sustainable Agriculture. CRC Press Tayloer and Francis Group. .Textbook -pp. 384 .ISBN 9781566702546
8) ISSS (2009) Fundamentals of Soil Science. 2nd Ed. Indian Society of Soil Science, New Delhi- 110 012. pp. 728.
9) Das D. K. (2011) Introductory Soil Science, 3rd revised and Enlarged Ed, Kalyani Publisher, Ludhiana. pp. 645.
10) ICAR Handbook of manures and fertilizers (1971) publication.
11) Tandon, HLS (2008) Fertilizers : Their composition, characteristics, quality, transformation and application. Fertilizer Development and Consultation, New Delhi, India pp. 137.
12) Somawanshi, *et al.* (2012) Laboratory Methods for Analysis of Soil, Irrigation Water and Plants.., Department of Soil Science and Agricultural Chemistry, MPKV., Rahuri. revised Ed. pp. 307.
13) Jakson, M.L. (1973) Soil Chemical Analysis. Printice Hall, India, Pvt. Ltd. New Delhi. pp 498.
14) Page *et. al.* (1982) Methods of Soil Analysis, Part 1 and 2. Chemical and Microbiological Properties . 2nd Ed. Soil Science Soc. of America Am. Soc. Agron., Madison, Wisconsin, USA.
15) Chapman, H.D., and P.F. Pratt. (1961) Methods of analysis for soils, plants and waters. Division of Agricultural Sciences, University of California.
16) Brady, N. C. (2016) The Nature and Properties of Soils. 15th edition Publisher: Pearson Education, ISBN: 978-0133254488.
17) ISSS. (2009) Fundamentals of Soil Science. 2nd Ed. Indian Society of Soil Science, New Delhi- 110 012. pp. 728.
18) Das, D. K. (2011) Introductory Soil Science, 3rd revised and Enlarged Ed, Kalyani Publisher, Ludhiana. pp. 645.
19) Tisdale, S. L. and Nelson, W. L. and Beaqton, J. D. (2010) Soil Fertility and fertilizers. 7th Ed. Macmillan Publishing Company, 445 Hutchinson Avenue, Columbus.
20) Yawalkar, K. S., Agarwal, J. P. and Bokde, S. (1967) Manures and Fertilizers. Agri-Horticultural Publication.
21) Chopra, S. L. and Kanwar, S. L. and Rakshit, J. S. (2014) Analytical Agricultural Chemistry. Kalyani Publisher.

Lesson No. 1 and 2

History of soil fertility and plant nutrition.

- ✓ Theoprastus (372-287 BC)
  - Recommended heavy manuring to light soils and sparingly manuring to the heavy soils.
  - Noted that urine can enrich the value of humus
  - Plant grows well where dead bodied are buried.
  - Advocated mixing of soil into another i.e. coarse soil into fine and fine soil into coarse soil.

- ✓ Xenophon (400 BC)
  - Recommended spring cropping.
  - Reported that microbial activities are their peak during spring.

- ✓ Cato (234-149 BC)
  - Grown green manuring crop on grape vine and buried at 50 % flowering to sustain soil fertility.

- ✓ Columella
  - Listed various legume crops for improvement of soil fertility.
  - Advocated spreading of lime and ashes to soil to destroy the acidity.

- ✓ Virgil (70-19 BC)
  - Advocated application of legumes.

- ✓ Francis Bacon (1561 to 1624)
  - Suggested that principle nourishment to plant was water and soil is only for supporting to plants i.e. anchor.

- ✓ Stephen Hales (1677 to 1761)
  - He is called first plant physiologist. He published the book 'Vegetable staticks' including substantial no. of experiments in plant physiology.

- ✓ J. Priestly (1733 to 1804)
  - Prepared O_2 by heating mercuric oxide. He observed that green plants emitted the same gas that was released by heated mercuric oxide and thus took the first step in clarifying the process of photosynthesis.

- ✓ Francis Home (1775)
  - Included air, water, salts, oil and fire in their fixed state. These were considered as stepping stone in development of modern agriculture.

- ✓ Sir Humphrey Davy
  - Published ‘Elements of Agril. Chemistry’ in 1813 and recommended the use of oil as fertilizer.

- ✓ Jean Bapstite Boussingnault (1802 to 1887)
  - He did the balance sheet of what is added and what is removed from soil.
  - He showed how much quantity of minerals comes from rain, air and soil.
  - He is also called the father of the field plot experimentation technique.

- ✓ Justus Von Leibig (1803-1873)
  - Discovered the ‘law of minimum’ and states that the growth of the plant depends upon the element in shortest amount all other elements being kept optimum.
  - He is also called the father of Agricultural Chemistry.
  - Developed fertilizers and fertilizer mixing.
  - Proposed separate branch of ‘Mineral nutrition of plants’

- ✓ J.B. Lawes and J.H. Gilbert
  - Founder of Agricultural experiments at Rothamsted station in England (1893).
  - Concluded that, cop requires both P and K, but plant ash can not be considered as the measure of these constituents.
  - The amount of ammonical nitrogen (NH_4-N) from atmosphere is insufficient for the crop needs. The non legume crops requires external supply of N from outward.

- ✓ Morgan (1852)
  - Developed a universal soil extractant for studying inorganic composition of soil material.

- ✓ Hoagland (1938)
  - He prepared a nutrient solution for plant growth. According to him plants requires 14 essential elements i.e. C, H, O, N, P, K, Ca, Mg, S, Fe, Zn, B, Cu and Mo.

- ✓ Velayuthan and Ghosh (1981)
  - Indian scientists prepared soil fertility maps of India. Concluded that soils of India are poor in soil fertility.

Lesson No. 3 and 4

Soil as a source of plant nutrients, essential and beneficial nutrients and their role. Criteria of essentiality, forms of nutrients in soil.

Definition of Soil

Soil is a dynamic natural body composed of mineral and organic material and living forms in which grow.

Essential nutrients

A chemical element required for normal growth of plant without which plant cannot complete its life cycle.

Example: - C, H, O, N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Bo, Mo, Cl, Ni.

Beneficial nutrients

Beneficial elements are the mineral elements which stimulate plant growth but are not essential or which are essential only for certain plant species or under specific conditions. Example – silicon, sodium, aluminium, cobalt selenium and vanadium,

Classification

I) Macronutrients - These are required in large quantities and there concentration in plant tissue is also more. There are nine macronutrients viz. C, H, O, N, P, K, Ca, Mg, and S. Secondary nutrients – Ca, Mg and S are required in relatively less quantity and they play secondary role in plant growth and hence are called secondary.

II) Micronutrients - These are required in very small amounts and therefore called as micronutrients. These are – Fe, Mn, Zn, Cu, B, Mo, Cl and Ni.

General functions of nutrients

1) As structural components of cell constituents and its metabolically active compounds
2) In maintenance of cellular organization
3) In energy forms formation
4) In enzyme action

Deficiency - When an essential elements is at low concentration that severely limits yield and produces more or less distinct deficiency symptoms. Extreme deficiency will lead to death of the plant.

Toxicity – When the Concentration of either essential or other element is high, enough to reduce plant growth and yield

Criteria of essentiality (Arnon, 1954)

- The given plant must be unable to complete its life cycle in the absence of the mineral element.
- The functions of the element must not be replaceable by another mineral element.
- The element must be directly involved in the plant metabolism.

Role of essential nutrients

Nitrogen

1. Essential part of proteins and is a constituent of physiologically important compounds like nucleotides, phosphatides, vitamins, enzymes and hormones.
2. Promotes rapid vegetative growth and improves the quality of leafy vegetables and fodder crops.
3. Integral part of the chlorophyll molecule and related to carbohydrate utilization.

Phosphorus

1. Constituent of nucleic acid, phytin and phospholipids.
2. Plays an important role in initiating primordial for the reproductive parts of the plants.
3. Major constituent of many enzymes associated with transformation of energy in metabolism of carbohydrates and respiration in plants.
4. Plays role in cell division and root development.

Potassium

1. Carbohydrate metabolism formation and breakdown and translocation of starch.
2. Nitrogen metabolism and protein synthesis.
3. Activation of various enzymes.
4. Adjustment of stomatal and water relation.
5. Increased vigour and resistance to disease and lodging.

Calcium

1. Growth of meristem and particularly for the proper growth and functioning of root tips.
2. Formation of middle lamella of cell wall in the form of Ca-pectate.
3. Neutralizing the phosphoric acid, citric acid, malic acid, oxalic acid which may become injurious to plants.
4. Increases protein content in mitochondria.

Magnesium

1. Act as catalyst in many important enzymatic and physiological reactions in plants.
2. Involved in oxidation of carbohydrate to CO_2 and H_2O.
3. Activates the enzyme associated with metabolism of N and synthesis of chlorophyll.
4. Governs the redox potential in plant cells during phases of light and darkness.

Boron

1. Enhances the permeability of the membrane and thereby facilitates carbohydrate transport.
2. Associated with cytokinine synthesis and cell division.
3. Regulates Ca uptake and K/Ca ratio in plant.
4. Essential for protein synthesis.

Zinc

1. Involved in biosynthesis of plant hormone indol acetic acid (IAA).
2. Component of metalloenzymes like carbonic anhydrase, alcohol dehydrogenase.
3. Important in neuleic acid and protein synthesis.
4. Helps in utilization of N and P in plant.

Molybdenum

1. Associated with nitrogen utilization and nitrogen fixation.
2. Important constituents of nitrate reductase and dehydrogenase enzyme.
3. Needed by *Rhizobium* in the process of N fixation.

Copper

1. Associated with cytochrome oxidase and component of many enzymes like ascorbic acid oxidase, phenolase, lactase etc.
2. It promotes formation of vitamin A in plants.

Forms of nutrients in soil

Sr. No.	Essential element	Ionic form absorbed by the plants
1.	Nitrogen	NH_4^+-N, NO_3^--N
2.	Phosphorus	$H_2PO_4^-$ (Water soluble) HPO_4^{2-} (Citrate soluble)
3.	Potassium	K^+
4.	Calcium	Ca^{2+}
5.	Magnesium	Mg^{2+}
6.	Sulphur	SO_4^{2-}
7.	Iron	Fe^{2+}, Fe^{3+}
8.	Manganese	Mn^{2+}, Mn^{3+}
9.	Zinc	Zn^{2+}
10.	Copper	Cu^{2+}
11.	Molybdenum	MoO_4^{2-}
12.	Boron	BO_3^{3-}
13.	Chlorine	Cl^-

Lesson No. 5 and 6

Introduction and importance of organic manures. Sources of organic matter, recycling, composition and C:N ratio.

Organic Recycling : Returning the plant nutrients removed by crops from soil through additions of organic material of crop after harvesting crop is referred as an organic recycling.

Sources of organic matter :

1. Primary source : Higher plant tissues
2. Secondary source : Animal and microorganism- Their remains and waste products.

Sources of organic residues used for manuring :

1. Rural 2. Urban 3. Industrial waste.

Manures : These are the materials naturally available in farm or locality and are constituted mainly of remains of plants and animals which are added to a soil as a source of nutrients and for modifying the soil properties.

Chemical composition of undecomposed organic matter:

1. Carbohydrates - 60 % ,
2. Proteins - 10 %
3. Fats, Waxes & tannins - 5%,
4. Lignins - 25 %

Elemental composition :

1. Carbon - 44 %,
2. Oxygen - 40 %
3. Hydrogen - 8 %,
4. Ash - 8 %

C/N ratio: The ratio of the weight of organic carbon to the weight of total nitrogen in soil or organic material.

C/N ratio in plants & Microbes and soil :

Legumes and farms manures	- 20:1 to 30:1
Straw residues	- About 100 :1
Saw dust	- 400 : 1
Microorganisms	- 4:1 to 9 : 1
Soil	- 10:1 to 12:1.

Significance of C/N ratio:

1. Effect on soil colour
2. Influence on physical properties.
3. High cation exchange capacity
4. Supply and availability of nutrients.
5. Effect on carbon cycle

Lesson No. 7, 8 and 9

Definition, properties and classification of bulky and concentrated organic manures, their composition and nutrient availability. Preparation of FYM, composts, different methods of composting, decomposition process and nutrient losses during handling and storage.

1) Bulky organic manures : Organic material of natural origin having greater volume per unit nutrient content. C/N ratio may be about 20 : 1

examples - FYM, compost and green manuring.

2) Concentrated organic manure : Organic material of natural origin having small volume per unit nutrient content. These are generally undecomposed having C:N ratio may be less than 10 : 1.

Examples - oil cakes, blood meal, meat meal, fish and bonemeal.

Concentrated organic manures :

Types : 1. Plant origin - oil cakes : Edible and non edible,

2. Animal origin - Bone meal, fish & blood meal, poultry manure.

1. Edible oil cakes ; Suitable for feeding to cattles also.

e.g. groundnut, cotton seed, linseed: sunflower, sesamum.

2. Non edible oil cakes : Not suitable for feeding to cattle.

e.g. caster oil cake, Karanj cake, Mahua cake, neem cake.

Factors affecting manurial value and decomposition of oil cakes.

1) C/N ratio
2) Oil content
3) Nutrificability
4) Presence or absence of nitrification retardars

Decomposition of organic compounds :

1. Sugars, starches and simple proteins. Rapid decomposition
2. Crude proteins
3. Hemicelluloses
4. Cellulose
5. Fats, waxes etc.
6. Lignins very slow decomposition

General reactions of decomposition:

1. Enzymatic oxidation with CO2, water, energy & heat as products.
2. Release of N, P and S
3. Formation of humus from resistant portion of organic material.

Bulky organic manures : Organic material of natural origin having greater volume per unit nutrient content. e.g. FYM, Compost, green manure etc.

Farm Yard Manure (FYM) : It constitutes the excreta of farm animals with or without an admixture of bedding or litter, fresh or at various stages of further decomposition.
FYM contains on an average 0.5 % N, 0.2% P_2O_5 and 0.5 % K_2O.

Preparation of FYM : Improved methods.

1. Trench method
2. Gobar gas plant and slurry
3. Enriched F.Y.M.

Composition of digested cattle dung slurry

Dry matter - 5.0 to 8.0 %
Organic matter - 60 to 70 %
Carbon - 35 to 42 %
Total N - 1.8 to 2.2 %
C/N ratio - 17 to 21

Losses during handling : Loss of liquid portion (Urine) and loss of solid portion (dung)
Losses during storage : 1) By leaching 2) By volatilization.

Control of losses :

Pakka floor,
Addition of gypsum or bedding material to absorb urine
Use of rock phosphate in pit
Maintain optimum moisture
Minimum turnings

Preparation of Compost:

1. Indore method or Heap method
2. Bangalore method or pit method
3. NADEP method

Factors affecting the process of composting :

1) C/N ratio,
2) Fineness of the material,
3) Moisture & aeration,
4) Temperature
5) pH,
6) Micro-organism,
7) Use of inoculants,
8) Calcium phosphate,
9) Destruction of pathogenic organisms.

Lesson No. 10 and 11

Vermicomposting, green manuring; types, advantages and disadvantages and nutrient availability.

Vermicompost :
Earth worms produce more compost in a shorter time with less efforts than any other method of composting.

Definition : The compost which is produced by earthworms having the highest grade and containing greater amounts of available / stable nutrients and high percentage of casting.

Earth worm casting : It contains humus, micro-organisms harmones, enzymes, auxin and other biomolecules.

Types of earth worms

1. Red worms - Lumbricus rubellus
2. Brandling worms - Eisenia foetida
3. Field worms - Allolobophora caliginosa

Method of vermicomposting in pit : Pit should be under shade.

1. Selection of earth worm : Use exotic detrivorus / epigeous species e.g. *Eudrilus easental, Eisenia foetida*.

2. Size of pit : Any convenient dimension such as 2 m x 1 m x 1 m may be prepared. This can hold 10-40 thousand worms.

3. Preparation of vermibed : A layer of 15-20 cm thick of good loamy soil above a thin layer (5 cm) of broken bricks and sand should made.

4. Inoculation of earth worms : About 2000 earthworms are introduced as an optimum density into a compost pit of 2m x 1m x 1m.

5. Organic layering : It is done on the vermibed with fresh cattle dung. The compost pit is then layered to about 5 cm with shredded organic litter of dry leaves or hay. Moisture level is maintained (without flooding) by addition of water.

6. Wet organic layering : It is done after four weeks with moist/ green organic waste and can be spread over it to a thickness of 5 cm. Practice is repeated every 3-4 days till compost is nearly full.
7. Harvesting : At maturation moisture content is brought down. This ensures drying of compost and migration of worms into vermibed. Mature compost is removed, sieved dried and packed.

Rate of application : Vermicompost is recommanded @ 5 t ha^{-1}.

Green manuring : Types, crops ,advantages and disadvantages.

Green manure : Plant material incorporated into soil while green or soon after maturity, for improving the soil.

Types of green manuring :

a) Green manuring in situ

b) Green leaf manuring

Decomposition in soil :

a) Aerobic : 1) Changes in carbon compounds

2) Changes in nitrogen compounds

3) Changes in mineral constituents.

b) Anerobic 1) Changes in carbon compounds

2) Changes in nitrogen compounds.

Green manuring crops : Sunhemp, Dhaincha, Green Gram, Cowpea, glyricidia and subabhul. Guar, Mung and berseem. Yield of these crops mode of incorporation into soil and nutrients added (For details refer the books.)

Advantages of green manuring :

1) Addition of organic matter

2) Increase in microbial activities

3) Returning of plant nutrients

4) Improving soil physical properties.

Disadvantages of green manuring:

1) Germination of crop affected

2) Loss of one season

3) More cost

4) Increase in pests and diseases .

Lesson No. 12 and 13

Sewage and sludge, Biogas plant slurry; their composition and effect on soil and plant growth.

Sewage : Liquid collected from closed drains usually contains urine and washings, the night soil and other solid ingredients.

Composition : N - 6 to 10%, P_2O_5 3 to 4% & K_2O 3 to 4%

Sludge : Settled sewage solids combined with varying amounts of water and dissolved materials removed from sewage by screening sedimentation. Chemical precipitation or bacterial digestion.

Composition:

N - 1.5 to 3.5%, P_2O_5 0.75 to 4.00 % and K_2O 0.3 to 0.6%.

Sludge effluent: The clear liquid that escapes from settling of sludge is known as sludge effluent.

Night soil : Human excreta consisting of solid portion as faces and liquid as urine.

Composition:

N-5 %, P_2O_5 4.0% and K_2O 2.0% carbon -45 to 50%.

Poudrette : The night soil is deposited in trenches and covered with a layer of earth and debris. This becomes dry material which is known as poudrette.

Effects of sewage, sludge and night soil on plant growth

Effects of sewage, sludge and night soil on soil.

Biogass slurry: N-1.6 to 1.8%, P_2O_5 1.1 to 2.0 and K_2O 0.8 to 1.2%

Lesson No. 14 and 15

Integrated nutrient management; concept, components and importance.

Integrated nutrient management (INM) is actually the technical and managerial component of achieving the objectives of IPNS under farm situations. It takes into account all factors of soil and crop management including management of all other inputs such as water agrochemicals etc, besides nutrients. IPNS, aims at efficient and judicious use of all these major sources of plant nutrient soil fertilizer, organic and biological in a integrated manner so as to maximize economic yields for a given cropping system and at the sources of plant nutrients.

The basic concept of integrated nutrient management is maintenance of plant nutrients supply to achieve a given level of crop production by optimizing the benefits from all possible sources of plant nutrients in an integrated manner, appropriate to each cropping system and farming situation. If the soil fertility has already ended to a high degree by in appropriate management practices, one major task of INM system will be to at least restrict the ongoing loss of surface or top soil nutrients.

The importance of integrated plant nutrient supply system was not realized earlier as nutrient removal by the crops was very low due to subsistence farming. Its need in modern agriculture has arisen due to

i. High price of chemical fertilizers
ii. Imbalance ratio of NPK consumption
iii. Imbalance in consumption and domestic production
iv. Deterioration of soil health
v. Consumption of non-renewable energy sources by inorganic fertilizers
vi. Pollution hazards of chemical fertilizers
vii. Loss of chemical productivity
viii. Deterioration in soil physical properties
ix. Deterioration in biological activity
x. Additive effect of organic and mineral fertilizers
xi. Organic materials as a source of secondary micronutrients
xii. Interaction benefit crops and reduction in crop productivity

Components of INM

1. Organic manures

The dead plant residues and animal remains were traditionally used in developing countries until the 1960’s when chemical fertilizers began to achieve popularity. Organic manures are generally of two types bulky organic manures and concentrated organic manures. The manures that are applied in large quantities and contain low amount of plant nutrients are known as bulky organic manures such as farm yard manure (FYM), compost, night soil etc. and concentrated organic manures contain higher percentage of major plant nutrients than bulky organic manures. The important concentrated organic manure are edible oil cakes (mustard, groundnut, seasame and linseed cake) and non edible cakes (castor, neem, sunflower, mahua and karanj cakes), blood meal, bone meal, fish meal etc. The inclusion of FYM regulates nutrient uptake improves crop yields and physical and chemical properties of soils and produces a synergistic effect.

2. Vermicompost

Vermicomposting is one of the best processes of recycling of different types of wastes available on farm, rural areas and urban settlements and may become most important component of INM system. It is a natural organic product which is eco-friendly and leaves no adverse effects either in the soil, produces or the environment. Thus, much interact in vermicomposting has bee notified due to the fact that earthworms play an important role in soil improvement, organic matter decomposition and in enhancing plant growth. The use of earthworms in organic waste management has been termed as vermicomposting and the compost is generally called as vermicompost. It is estimated that 1800 worms which is ideal population for one sq. meter can feed on 80 tonnes of humus per year. The worm commonly used for this purpose is *Eisenia fetida*, *Eudrillus eugeniae* and *Pheritima elongate* which is potential reagent in breaking down animal waste. On an average, it contains 1.6 per cent N, 5.04 per cent P_2O_5 and 0.8 per cent K_2O. Apart from this it also contains hormones like auxins and cytokinins, enzymes, vitamins and useful micro-organisms like bacteria, actinomycetes, protozoa's, fungi and others.

3. Green manuring

Green manuring is the cheapest resource for building up soil fertility and supplementing plant nutrients, especially N. The practice of ploughing in of undecomposed green plant material into the soil for improving the physical condition as well as fertility of the soil is called as green manuring. Green manures may be grown *in situ* by raising a legume such as *Sesbania aculeata* (dhaincha), *Crotolaria junica* (sunhemp) and *Vigna unguiculata* (cowpea) are capable of accumulating 4-5 t ha^{-1} of dry mass and about 100 kg N ha^{-1} in 50-60 days. Integrated use of green manures with recommended chemical fertilizers increases the yields of field crops.

4. Biofertilizers

Biofertilizers have been recognized as important inputs in INM system and their use of recent origin. They are apparently environmentally friendly, low cost and non bulky agricultural inputs which play a significant role in plant nutrition as a supplementary and complementary factor to mineral nutrition.

Name of organism	Mode of action	Crops for which used	Method of treatment
Rhizobium	Symbiotic N fixation	Leguminous pulses, fodder crops and groundnut	Seed treatment
Azotobacter	A symbiotic N fixation	Cereals, vegetables, millets and cotton	Seed treatment
Azospirillium	A symbiotic N fixation	Cereals and millets,	Seed treatment
		vegetable crops	Soil application
Blue green algae	A symbiotic N fixation	Paddy	Soil application
Azola	A symbiotic N fixation	Paddy	Soil application
Phosphobacteria	Phosphorus solubilizing	Millet, wheat and paddy	Seed treatment

5. Crop residues

Residues left out after the harvest of the economic portion is called as crop residues on an average, it contains 0.5 per cent N, 0.6 per cent P_2O_5 and 1.5 per cent K_2O. Crop residues mostly are staple food of cattle and dry fodder for animal. In certain regions where mechanical harvesting is done the crop residues are left behind in the field which act as a source of nutrient supply. Crop residues improve the soil physical properties, micronutrient supply and productivity. The major advantages of residue incorporation is the increase of the soil organic carbon, total N and available K. The incorporation of crop residues on a long form basis also increased the DTPA extractable Zn, Cu, Fe and Mn content in soil. Judicious use of crop residues is an important consideration in reducing the nutrient losses through leaching, volatization or fixation specially under adverse soil conditions. Direct application of crop residues with wide C:N ratio may immobilize all the available N and P leading to adverse effect on crop growth during initial periods of decomposition. Introduction of certain microbial strains capable of accelerating carbon mineralization can cut short the time necessary for complete residue decomposition.

6. Crop rotation

7. Legume intercropping

8. Chemical fertilizers

The role of chemical fertilizers in increasing crop yields has become obvious with the introduction of high yielding varieties responding to fertilizers. Most of the soils are only able to supply a fraction of the nutrients required by the arable crops. Even available nutrients are rarely present in appropriate proportion to meet the crop needs. Due to intensive cropping with high nutrient responsive varieties, widespread deficiencies of micronutrients particularly Zn are emerging as yield limiting factor. Hence, the deficient micronutrient should be applied through their respective carriers in soil, if soil is Zn deficient, then $ZnSO_4$ application should be done.

Lesson No. 16 and 17

Fertilizer; Definition and their classification; N fertilizers: classification, manufacturing process and properties their fate and reaction in soils.

Fertiliilzers : Any organic or inorganic material of natural or synthetic origin added to a soil to supply certain element essential for the growth of plants.

Fertilizers are classified on the basis of major nutrient content.

1. Nitrogenous fertilizers ;
2. Phosphatic fertilizers ;
3. Potassic fertilizers,

Classification of nitrogenous fertilizers : Nitrogenous fertilizers are classified into four groups on the basis of chemical form in which nitrogen is combined with other elements.

1. Nitrate fertilizers: Nitrogen is in. oxidised form i.e. NO_3

e. g. a) Sodium nitrate ($NaNO_3$) - 16 % N

b) Calcium nitrate [($Ca(NO_3)_2$)] -- 15.5 % N

2. Ammoniacal fertilizers: Nitrogen is in reduced form i.e. NH_4-N

e.g. i) Ammonium sulphate [$(NH_4)2SO_4$] --- 20 % N

ii) Ammonium chloride (NH_4CI) -- 26 % N

iii) Anhydrous ammonia - 82 % N

iv) Ammonium phosphate ($NH_4H_2PO_4$) - 20% N + 20 % P_2O_5

16 % N + 20 % P_2O_5

3. Nitrate and ammonium fertilizers : Nitrogen is in the form of NO_3-N + NH_4-N e.g.

i) Ammonium nitrate (NH_4NO_3) --- 34% N

ii) Calcium ammonium nitrate ---- 26 %N

iii) Ammonium sulphate nitrate --- 26 % N

4. Amide fertilizers: Organic nitrogenous fertilizers nitrogen, in amide (NH_2) form e.g.

i) Urea [$CO(NH_2)_2$] ------- 46 % N

ii) Calcium cynamide ($CaCN_2$) ----- 21 %

Sources of nitrogen : Mineral deposits, rain water, soil organic matter, atmospheric N and industrial source.

Manufacturing of Urea :

Urea is manufactured by reacting anhydrous ammonia and carbon dioxide gas under very high pressure in the presence of suitable catalyst.

i) $2NH_3 + CO_2 = NH_2COONH_4$

(an unstable intermediate product)

ii) $NH_2COONH_4 = CO(NH_2)_2 + H_2O$

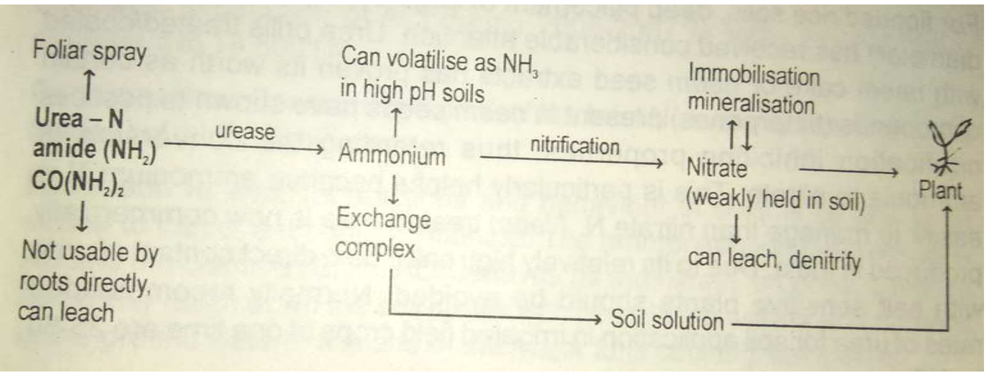
The urea solution is concentrated to 99% and is sprayed into a chamber where urea crystal are formed.

Fate of nitrogen in soil:

- Nitrate nitrogen of the soil, added or formed by nitrification, may be loss in four ways,

i) Volatilization loss
ii) Leaching loss
iii) Denitrification
iv) Used by microorganisms and weeds

Fate of urea in soil:



Management of nitrogenous fertilizers:

1. For paddy , ammonical and ammonia forming fertilizers should be used.
2. For all other field crops, a II nitrogenous fertilizers are equally effective.
3. On acid soils or soils low in lime/calcium, continued use of ammonium sulphate, urea, ammonium chloride and ammonium sulphate nitrate should be avoided.
4. A nitrate fertilizer. like sodium nitrate is suited for top dressing and side dressing when growing crops need nitrogen immediately.
5. Since nitrate fertilizers are easily leached, they should not be applied in large quantities in light sandy soiIs or during the rainy season. In sandy soils, the entire recommended dose of nitrogen should be applied in split doses.
6. In the winter or rabi season, the nitrogenous fertilizer should be selected on the basis of cheapness per unit kg of nitrogen; as all nitrogenous fertilizers are equally effective and loss of nitrogen due to leaching does not usually occur.

Lesson No. 18 and 19

Phosphatic fertilizers, manufacturing process and properties, classification, their fate and reaction in soils.

Phosphatic fertilizers : Manufacturing process and properties of single super phosphate, enriched super phosphate, ammonium phosphate, ammonium polyphosphate

Classification of phosphatic fertilizers : Phosphatic fertilizers are classified into three groups, depending *on* the *form* in .which orthophosphoric acid/phosphoric acid is combined with calcium.

1. Water soluble/Monocalcium phosphate: $Ca(H_2PO_4)_2$

- i) Single super-phosphate - 16% P_2O_5
- ii) Double super-phosphate - 32 % P_2O_5
- iii) Triple super-phosphate - 48 % P_2O_5
- iv) Ammonium phosphate - 11 %N + 52% P_2O_5

2. Citric acid soluble/Dicalcium phosphate ($CaHP0_4$)

- i) Basic slag - 14 to 18 % P_2O_5
- ii) Tricalcium phosphate - 34% to 39 % P_2O_5

3. Insoluble/Tricalcium phosphate - $Ca_3(PO_4)_2$ Acid soluble

- i) Rock-phosphate - 20 to 40 % P_2O_5
- ii) Raw bonemeal - 20 to 25 %10 P_2O_5
- iii) Steamed bonemeal - 22 % P_2O_5

General characteristics of phosphatic fertilizers :

1 . Water soluble/Monocalcium phosphate
2. Citric acid soluble/Dicalcium phosphate
3. Insoluble/Dicalcium phosphate

Manufacturing of single super phosphate:

- ✓ Approximately equal amounts of rock phosphate and Conc. Sulphuric acid (70 %) are weighed separately and mixed for about one minute in mechanical rotators.
- ✓ The warm mixture is then falls through a flap into a huge den where chemical reactions continue.
- ✓ The mixture is left in den for 12 hrs to harden and cool down.
- ✓ Then, it is removed by a crane and deposited in a large shed to mature.
- ✓ After some weeks, it becomes ready for use.
- ✓ Before bagging, it is necessary to grind the fertilizer.
- ✓ **Thus, <u>two important ingredients of superphosphate</u> are Monocalcium phosphate and Gypsum.**

Reactions of single super-phosphate in soils :

a) Neutral soils

$Ca(H_2PO_4)_2 + Ca(HCO_3)_2$ ----- $2CaHPO_4 + 2H_2CO_3$

b) Alkaline soils

1) $Ca(H_2PO_4)_2 + Ca(HCO_3)_2 = 2CaHPO_4 + 2H_2CO_3$

2) $Ca(H_2PO_4)_2 + 2Ca(HCO_3)_2 = Ca(PO_4)_2 + 4H_3CO_3$

c) Acidic soils:

$2Ca\ (H_2PO_4)_2 + Fe\ _2O_3 = 2\ Fe\ PO_4 + 2\ CaHPO_4 + 3\ H_2O$

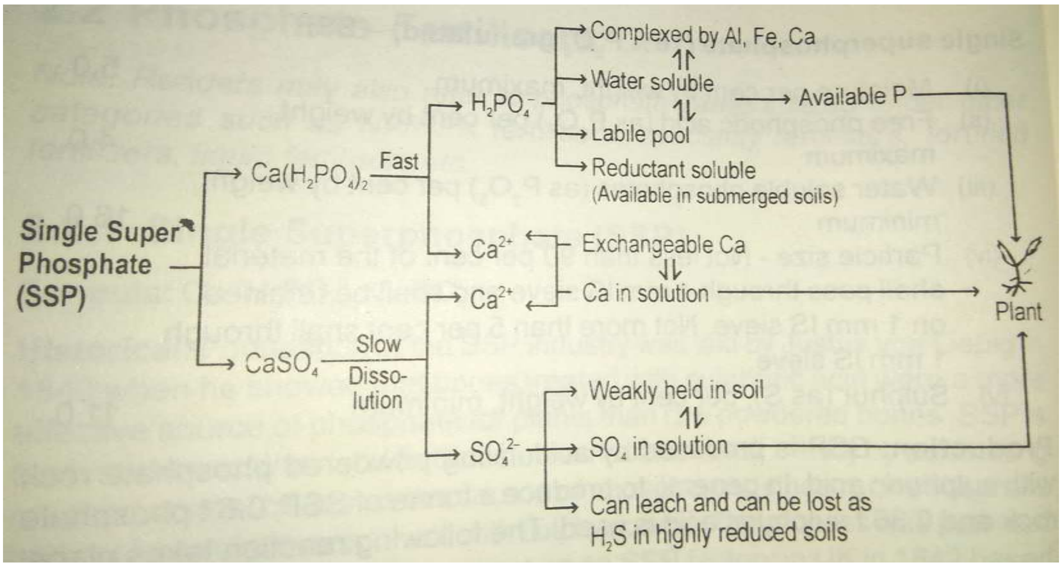
Reactions of Rock-Phosphate in soils :

a) Acidic soils

i) $[Ca_3(PO_4)\ _2]\ 3CaCO_3 + 6H_2CO_3 = 3Ca(H2PO_4)_2 + 7CaCO_3$

ii) $[Ca_3(PO_4)_2]\ 3CaCO_3 + 14HNO_3 = 3Ca(H_2PO_4)_2 + 7Ca(NO_3)_2 + H_2CO_3$

Fate of SSP in soil



Management of phosphatic fertilizers:

1. Water soluble phosphatic fertilizers are suitable for slightly acidic, neutral or alkaline soils.
2. W.S.P. fertilizers are applied to soils when crop requires a quick start.
3. W.S.P. fertilizers are suitable for short duration crops like paddy, wheat, jowar, ragi, maize, soybeans, cabbage, cauliflower, potato, gram & Vegetable crops.
4. Citrate soluble phosphatic fertilizers are suitable for moderately acidic soils, long duration crops like sugarcane, tapioca, tea, coffee, legume & pastures.
5. Insoluble phosphatic fertilizers are suitable for the soil which is strongly to extremely acidic & long duration fruits crops.
6. SSP should be applied to the soil just before sowing in single dose.
7. SSP is unsuitable for top-dressing due to slow mobility for short duration crops and it should not be used in acidic soils.

Lesson No. 20 and 21

Potassic fertilizers: classification, manufacturing process, properties, their fate and reaction in soils. Complex fertilizers their fate and reaction in the soil. Nano fertilizers.

Potassic fertilizers

Classification of Potassic fertilizers

Potassic fertilizers are mainly classified into

1) Fertilizers having K in the chloride form e.g. KCl

2) Fertilizers having K in non-chloride form e.g. K_2SO_4 and KNO_3.

Source of potassic fertilizers : Mainly from water soluble potash minerals, and small extent from brine. The potash containing soluble minerals are

1) Sylvite KCl 63.1 % K_2O

2) Carnallite KCl. $6H_2O$ 17.0 % K_2O

3) Kainite KCl. $MgSI_4.3H_2O$ 18.9 % K_2O

4) Langbeinite $K_2SO_42MgSO_4$ 22.6 % K_2O

5) Sylvinite (mixture) 20.3 % K_2O

Classification and properties of potassic fertilizers

1) Potassium chloride / muriate of potash (KCl)

- K with Cl as anion chloride containing fertilizer.
- K_2O content 55 – 50 %
- Mineral used sylvite and carnalite

2) Potassium sulphate (K_2SO_4)

- Non chloride fertilizer
- Pure salt content – 54 % K2O
- Commercial salt content – 48 % K2O
- Mineral used kainite and longbeinite

3) Shoenite : K_2SO_4. $MgSO_4.6H_2O$

- It is double salt of SO_4 with K and Mg
- It is by product of marine salt works
- K_2O 25-30 %
- MgO 10-12 %

Manufacturing of MOP

It is manufactured from potash bearing minerals mainly by two processes,

i) Crystallization: The principle involved in this process is that KCl is much more soluble in hot water than cold. While, the solubility of NaCl is not vary with temperature.

ii) Floatation: This method is based on the differences in specific gravity of KCl and NaCl. KCl having less Sp. Gravity floating on top of NaCl.

Manufacturing of SOP

i) By dissolving langbeinite in water and adding a conc. solution of KCl. The potassium sulphate is precipitate out and is separated by decantation.

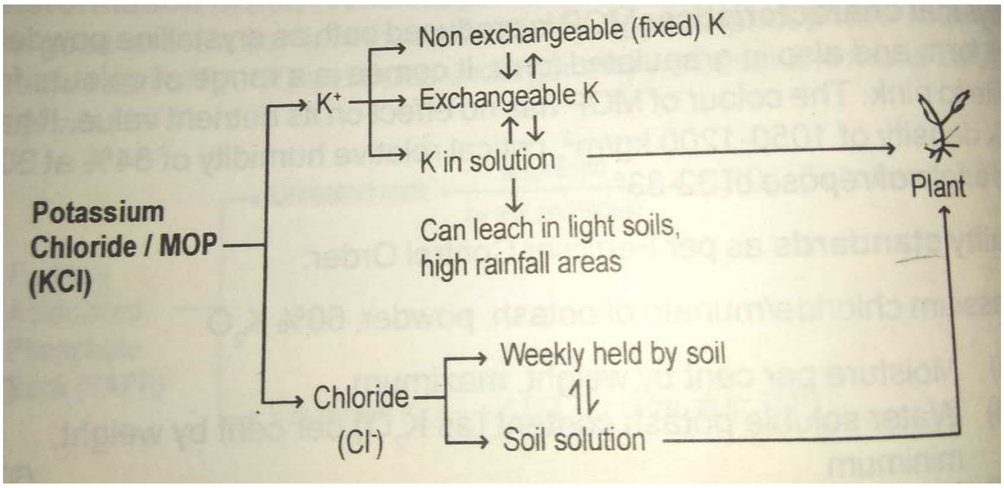
$$K_2SO_4.2MgSO_4 \quad + \quad 4KCl \quad = \quad 3K_2SO_4 \quad + \quad 2MgCl_2$$

langbeinite

ii) By treating KCl with Conc. H_2SO_4

$$2KCl \;+\; H_2SO_4 \quad = \quad K_2SO_4 \quad + \quad 2HCl$$

Fate of MOP in soil



Management of potassic fertilizers :

KCl is cheaper fertilizer and extensively used by the cultivators for all crops except where no chloride is desired in the fertilizer, e.g. Tabacco.

K_2SO_4 is some what costlier on the basis of per unit of K as compared to KCl and used for the crops like potato, tobacco and tomato.

Complex fertilizers

The commercial fertilizers containing atleast two or more of the primary essential plant nutrients (N, P, K) are called complex fertilizers. When the fertilizer contains only two of the primary nutrients it is designated as incomplete complex fertilizer, while one containing all three primary major nutrients (N, P and K) is designated as complete complex fertilizer.

These fertilizers are manufactured in general by :
a) Chemical reaction and b) Purely mechanical mixing *of* straight fertilizers.

Characteristics of complex fertilizer :

1. High analysis fertilizers
2. Have Uniform grain size
3. Cheaper on the basis of nutrient content per Kg.
4. Transport and distribution cost is less
5. Safe for storage
6. Desirable as these contain balanced nutrients *for* applications.
7. Non caking and non hygroscopic.

Advantages of complex fertilizers :

1. Easy application
2. Balanced crop nutrition.
3. High fertilizer efficiency
4. Even distribution of nutrients
5. Saving of Iabour and time
6. Safe for storage.

High analysis fertilizer : Fertilizers have a high content of total plant nutrients more than 30 kg per 100 kg of fertilizer.

Manufacture, properties and nutrient content of complex fertilizers
Nitrophosphate : Manufacture :

1. Nitro carbonic process
2. Nitro-separation process
3. Process involving nitric acid & phosphoric acid
4. Process involving nitric acid.

Properties of nitrophosphates :

1. Granulated fertilizer containing stabilizer
2. Contains Nitrogen as well as phosphorus
3. Excellent physical conditions during storage and handling.

RCF (Trombay) manufactures three types of nitrophosphates

1) Suphala (20:20:0) 2) Suphala 3) Suphala (15:15:15).

Ammonium phosphate : Manufactured by combing ammonia with phosphoric acid. Monoamonium phosphate. (MAP). Diaimmonium phosphate (DAP) is popular having 11 :52:0 and 18:46:0 grades respectively.

Characteristics of Ammo. Phosphates:

1. Slightly grey material
2. Slightly acidic to neutral
3. Produce acidity in soil if used continuously and require 80 Kg of $CaCO_3$ to counteract its acidity
4. It is least hygroscopic.

Various grades of ammonium phosphates are manufactured. NPK Complex fertilizers: Complex fertilizers containing various composition of N, P and K. These are manufactured for application to various crops.

Value of complex fertilizers : The value of complex fertilizers is dependent on the following considerations.

1. Their content of individual nutrients and ratio of N, P, K.
2. Form in which individual nutrients are present
3. The resultant basic or acidic residual effect.
4. These contain trace elements and contamination substances viz. chlorides, sulphates etc.

Nano fertilizers

Agricultural scientists are facing a wide spectrum of challenges such as stagnation in crop yields, low nutrient use efficiency, declining soil organic matter, multi-nutrient deficiencies, climate change, shrinking arable land and water availability and shortage of labour besides exodus of people from farming. In spite of immense constraints faced, we need to attain a sustainable growth in agriculture at the rate of 4% to meet the food security challenges. To address these problems, there is a need to explore one of the frontier technologies such as 'Nanotechnology' to precisely detect and deliver the correct quantity of nutrients and pesticides that promote productivity while ensuring environmental safety and higher use efficiency. The nanotechnology can be exploited in the value chain of entire agriculture production system. **Nanotechnology deals with the matter at nanoscale (1-100 nm) dimensions.** These materials when reduced to the nanoscale show some properties which are different from what they exhibit on a macro scale, enabling unique applications. Nanoscience has brought revolution in different fields by helping develop processes and products that are hardly possible to evolve through conventional methods.

Coating and binding of nano and subnanocomposites are able to regulate the release of nutrients from the fertilizer capsule. In this regard, Jinghua (2004) showed that application of a nano-composite consists of N, P, K, micronutrients, mannose and amino acids enhance the uptake and use of nutrients by grain crops. Moreover, nanotechnology could supply tools and mechanisms to synchronize the nitrogen release from fertilizers with crop requirements. This will be accomplished only when they can be directly internalized by the plants. Zinc–aluminium layered double-hydroxide nanocomposites have been employed for the controlled release of chemical compounds which act as plant growth regulators. Studies has shown that fertilizer incorporation into cochleae nanotubes (rolled-up lipid bilayer sheets), had improved crop yield. More recent strategies have focused on technologies to provide Nano fertilizer delivery systems which can react to environmental changes. The final goal is production of Nano fertilizers that will release their shipment in a controlled manner (slowly or quickly) in reaction to different signals such heat, moisture and etc.

Dr. Vikrant P. Bhalerao
(Assistant Professor)
Dept. of Soil Science and Agril. Chemistry
College of Agriculture, Dhule