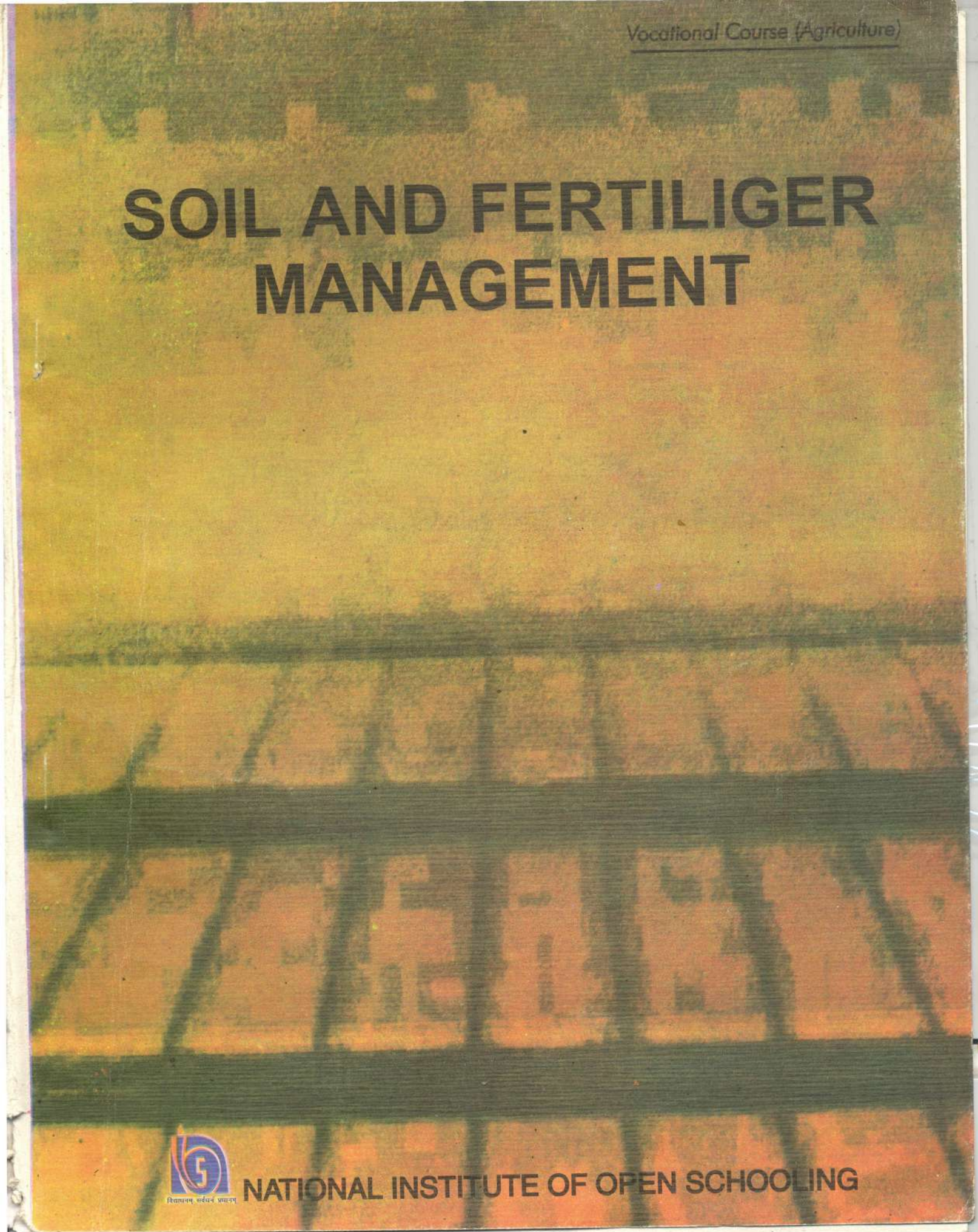
Vocational Course (Agriculture)

SOIL AND FERTILIGER MANAGEMENT



NATIONAL INSTITUTE OF OPEN SCHOOLING

SOIL AND FERTILIZER MANAGEMENT

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Part IV A (Article 51 A)

It shall be the duty of every citizen of India -

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(c) to uphold and protect the sovereignty, unity and integrity of India;

(d) to defend the country and render national service when called upon to do so;

(e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(f) to value and preserve the rich heritage of our composite culture;

(g) to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(i) to safeguard public property and to abjure violence;

(j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement.

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CURRICULUM

Title of the Course : Soil and Fertilizer Management

Level : Senior Secondary

Entry Qualification 10th passed or equivalent

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		Chemical properties of soil-soil reaction (pH), soil colloids, electrical conductivity, cation and anion exchange capacities organic matter.
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33. Visit to a sewage treatment plant
34. Visit to a Municipal compost plant

SCHEME OF STUDIES : (a) Theory (60%)

(a) Practiclas (40%)

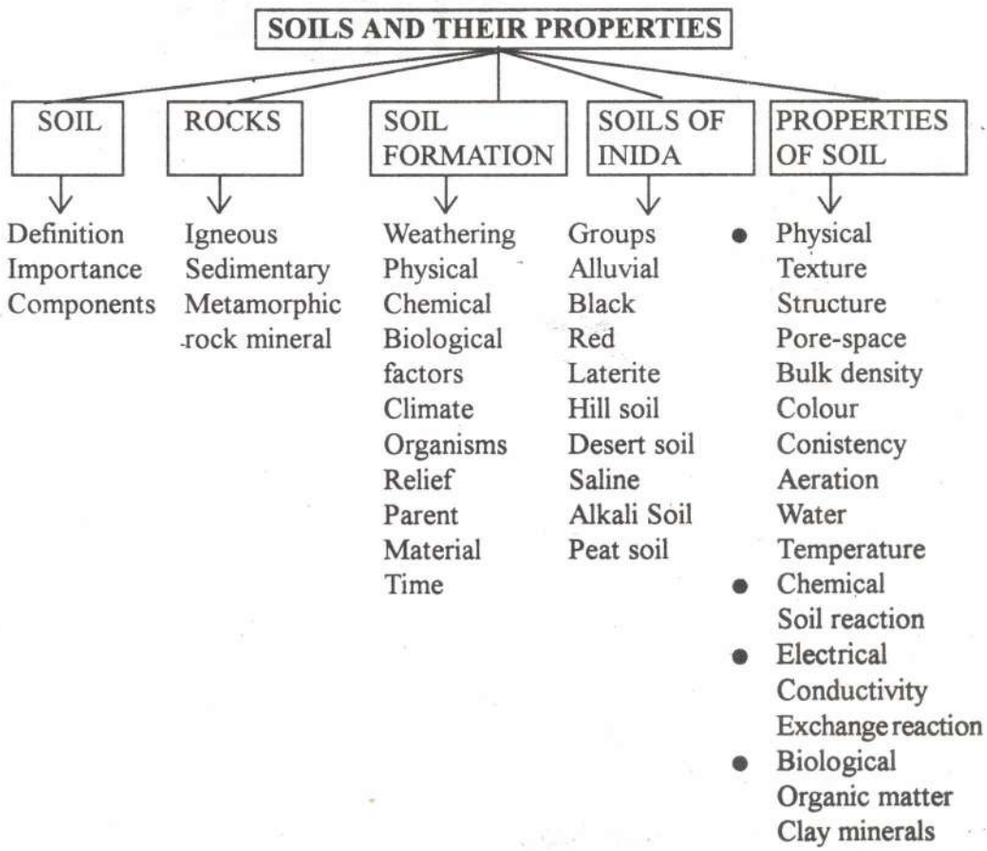
Module -1

SOILS

INTRODUCTION

Soil is a natural resource which forms a basis for agriculture. It not only serves as a reservoir of food materials and water needed by the plants, but also provides a mechanical anchorage for them. The importance of soil in agriculture has been recognised by man since time immemorial. For efficient management of this soil to achieve targeted food production, knowledge about soil, their behavior and their influence on crop growth is needed. Therefore this lesson aims to provide basic information about soil and how it is formed.

KEY CONCEPTS



OBJECTIVES

After studying this lesson you will be able to:

- define soil, rock and minerals;
- describe how soils are formed;
- state various factors influencing the soil formation;
- list and define various physical properties of soil;
- describe some important chemical properties of soil;
- state various micro-organisms involved in biological processes;

Along with atmosphere, soil constitutes the natural medium which supports the growth of plants on earth's surface. Soil may be defined as a natural body of loose, unconsolidated material which constitutes a thin layer of earth's crust. It is made up of small particles of decomposed rocks, organic matters, water, air and living organisms.

For a farmer the term 'soil' refers to the cultivated top layer only, that is up to 15 to 20 cm of the plugs depth. Subsoil is the level below the surface and differs from it in many ways.

1.1.1 IMPORANCE OF SOIL

- Soil provides physical support and shelter.
- Soil supplies essential nutrients for plant growth.
- Soil forms substrate for microorganism.
- Soil provides water and air needed for plant growth.

1.1.2 COMPONENTS OF SOIL

A well formed soil is composed of four major components.

1. Minerals
2. Air
3. Water
4. Organic matter (humus) and micro-organism

An ideal distribution of these components in soil is shown in Figure 1.

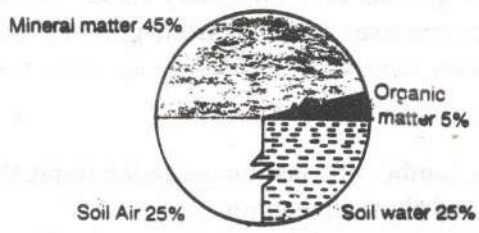


Figure 1 Proportions of the main soil components (volume basis)

Mineral matter : This constitutes about 45% of soil volume. The mineral particles mainly determine the mechanical properties of the soil. Mineral particles are formed from the weathering of the various parent rocks.

Air : Soil air occupies about 25% of the soil volume. The soil air consists primarily of nitrogen and oxygen. It usually contains higher concentrations of carbon dioxide than the atmosphere and traces of other gases that are produced by microbial metabolism.

Water : Soil water makes up about 25% of the soil volume. The soil water contains organic and inorganic substances, plant nutrients and is called as soil solution.

Organic matter : About 1 to 5% of the soil volume is constituted by organic matter (humus). Organic matter is a storehouse of plant nutrients and is a source of food for soil micro-organisms.

The relative amount of each component varies from soil to soil and also with depth within soil from the same site. Either singly or in combination, these components are largely responsible for the fertility of soils.

1.2 ROCKS

Soils are formed by the disintegration and decomposition of rocks, plants and animal residues, through the action of climate and living organisms on the parents rock over a long period of time. Rocks form parent materials to soils.

Rocks consist of hard (consolidated) or soft (unconsolidated) mineral and organic deposits. There are three types of rocks: (i) igneous rocks, (ii)sedimentary rocks and (iii) metamorphic rocks.

1.2.1 Igneous Rocks

These are the primary rocks formed directly from the molten lava. Rocks containing a high proportion of quartz are grouped as acidic, whereas those rich in iron, aluminum, calcium, magnesium, sodium, etc., are known as basic rocks. The most common igneous rocks found in India are the granites (acidic) and the basalt (basic).

1.2.2 Sedimentary Rocks

These are derived from igneous rocks. The more commonly known sedimentary rocks are sandstone clay, shale and limestone.

1.2.3 Metamorphic Rocks

They are formed from igneous or sedimentary rocks. The common examples of metamorphic rocks are gneisses (derived from granite), quartzite (derived from quartz, sandstone's), slates (formed from Shale's) and marble (derived from limestone).

1.2.4 Rock minerals

Rock is composed of a number of constituents called minerals, which have definite chemical composition and physical features.

Though there are number of minerals, a few only are the major constituents of the more common rocks and they can be easily identified with a little experience. The two most abundant elements in the earth's crust are silicon and oxygen. Combinations of these two elements form the basis for all types of silicate minerals that occur in rocks and soils. Some important rocks forming minerals which contribute to the formation of major soils in India are as follows.

Quartz; Feldspars; Micas; Ferro-magnesium silicate mineral; and Olivine

Most of these minerals are silicates of one type or another and form soils on weathering. Among the silicate minerals the feldspars are very prominent in the soil-forming rocks.

1.3 SOIL FORMATION

Soils are formed by the mechanical disintegration and chemical decomposition of parent rock that make up the earth's crust. The breaking up of rocks is generally termed as weathering. Weathering refers to many processes which cause changes in the nature of rocks nd minerals to form the soil.

1.3.1 Weathering

The rocks are subject to the action of climate, moisture, plant, animal life and similar agenices and get disintegrated slowly into smaller particle. This is referred to as physical weathering.

Then these smaller particles are acted upon by water, carbonic acid and organic acids which are formed during the decomposition of organic matter. Ultimately, clay, sand and other secondary minerals are produced. These changes in mineralogical and chemical composition of the material is referred to as chemical weathering.

These two weathering processes occur simultaneously and are interdependent with each other. The materials so formed are subject to further weathering and change leading to formation of soil. As a result, the rock material changes its original appearance and properties.

Physical Weathering

The principal agents of physical weathering (disintegration of rocks) are the following.

Heat

Water

Wind

Plants and animal

Chemical Weathering

The chemical decomposition of rocks is brought about by hydrolysis acidification, carbonation, oxidation and reduction.

- **Biological Weathering**

In addition to physical and chemical weathering, there is also the weathering induced by living organisms or biological agencies, which include both plant and animal organisms. The plant and animal residues add organic matter which is incorporated with weathered mineral matter and brought about changes. Biological agencies also play vital role in the formation of soil. Therefore soil formation is a biochemical process.

1.3.2 Factors of soil formation

There are number of factors influence the soil formation.

However, only five factors are considered important. They are :

a) Climate (CL)

b) Organisms (O)

c) Relief (R)

d) Parent material (P)

e) Time (T)

According to Professor Jenny (an American soil scientist) these soil forming factors can be expressed by the following equation:

Soil (s) = f (cl, o, r, p, t)

These factors are briefly discussed in the following section.

1.3.2.1 Climate

Climate is often considered to be the most important soil forming factor. The two components that most strongly influence soil formation are precipitation (rainfall) and temperature. Water is an extremely important component of all chemical and many physical weathering processes. Temperature has a marked influence on the rate of weathering.

1.2.3.2 Organisms

Various types of plant and animal present in an area will have a significant effect on the type of soil formed. For example organic matter accumulation, profile mixing, nutrient cycling, soil physical properties are all enhanced by the activities of living organisms in the soil. The activity of man also affects soil formation. The use of organic manures and fertilizer, cultivation practices, and other activities like deforestation, all have influence on soil formation.

1.2.3.3 Relief

There are three main ways in which the shape of the landscape (topography) can affect soil formation: (i) through the influence of slope on soil depth, (ii) by modification of the effects of climate, and (iii) by influencing the moisture relationship. For example, soil depth is strongly influenced by the shape of the land.

1.2.3.4 Parent material

The characteristics and type of soil are significantly influenced by parent material. Not only during the process of development, but also in well developed soil, the influence of parent materials from which the soils are formed is considerable. The mineral content of parent material (rock) largely determines the chemical components of soil. This is especially true in relation to the formation of the different types of clay minerals. It is not noly the chemical and mineral composition of the parent material that can affect soil formation, its physical nature is also important.

1.2.3.5 Time

The processes of soil formation discussed above take place gradually over substantial period of time. The terms soil development refers to the changes with time that take place in the soil as a result of these various processes. In the initial stages of soil formation, changes are related mainly to the accumulation of organic matter. With further time, changes in the chemistry, mineralogy and physical characteristics of the developing soil will be occurring. The age of the soil is generally considered to be length of time that parent materials have been subjected to weathering.

1.3.3 Soil Profile

For a study of the soil in its undisturbed condition in the fields, a vertical section up to the parent rock is usually examined. The vertical cross section of soil is known as soil profile. It is often differentiated into easily distinguished horizontal layers, which are referred to as horizons. The horizons above the parent material are collectively referred to as the solum (a Latin term meaning soil of land).

A typical soil profile with different horizons is illustrated in Figure 2.

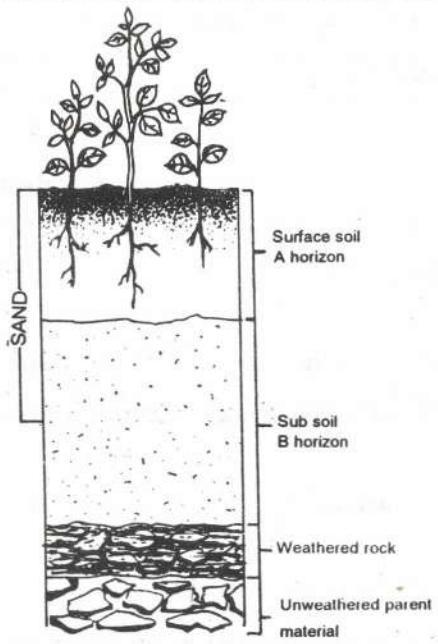


Figure 2 **A representative soil profile**

Every well developed, undisturbed soil has its own distinctive profile characteristics. The horizons are of varying thickness, colour, texture, structure and also in chemical properties.

Generally speaking, the profiles consist of three distinct horizons shown as A, B, and C. 'A' horizon forms the surface soil of the plugs layer. 'B' horizon is the layer next below, in which part of the products leached out from 'A' horizon has been deposited. It is termed as sub-soil. Immediately under it is the upper part and unweathered rock belwo. The 'A' and 'B' horizons form the true soil or solum.

1.4 SOILS OF INDIA

In the preceding sections of this module we have seen that various factors like climate, organisms, parent material, relief and time influence the soil formation. Depending upon the magnitude of their effect, different groups of soils are formed. In Inida, the soils have been classified into the following major groups:

1. Alluvial soils
2. Black soils
3. Red soils
4. Laterite and lateritic soils
5. Mountain and hill soils
6. Arid and desert soils
7. Saline and alkali soils

Alluvial soil is the most extensive soil group, followed by black soil in India. Some important charcteristics of major soil groups are discussed in the practical.

INTEXT QUESTIONS 1.1

A. Fill up the blanks

1. A loose, unconsolidated material which constitutes a thin layer of earth's crust is called .....
2. Water occupies about.....% whereas mineral matter occupies about .....% of the soil volume.
3. Soils are formed by the .....and .....of rocks.
4. The three types of rocks generally occuring in India are.....,....., and.....
5. .....are silicate minerals which are very prominent in the soil forming rocks.
6. Mechanical disintegration of rocks into smaller particles is termed .....
7. Among the factors which influence soil formation.....is considered to be the most important.

8. .....deterine the chemical composition of soil .

9. A vertical cross-section of soil is generally referred to as..... and the horizons above the parent material are collectively referred to as.....

10. In India..... soil occupies the largest area followed by.....

B. Choose the correct answer

1. The primary rocks formed directly from the molten lava are
   a) Parent material
   b) Metamorphic rocks
   c) Igneous rocks
   d) Sedimentary rocks

2. The most common igneous rocks found in India are
   a) Quartz
   b) Marble
   c) Sand Stones
   d) Granites

3. The decomposition of parent rock is a process of
   a) Mineralization
   b) Physical weathering
   c) Chemical weathering
   d) Soil formation

4. The components of climate which play very important role in soil formation are
   a) Wind and humidity
   b) Rainfall and temperature
   c) Sunshine and rainfall
   d) Evaporation and temperature

5. State 'True' or 'False'
   a) 'A' horizon only forms soil
   b) 'B' horizon is sub-soil
   c) Horizons are horizontal layers.
   d) The characteristics of profile will not change due to climate
   e) 'C' horizon is important for crop growth.

1.5 PROPERTIES OF SOIL

Soil is regarded as a living material and does possess different physical, chemical and biological properties. Depending upon the effect of various factors and processes of soil formation, properties of soil vary. In this section, let us lern about various properties.

1.5.1 Physical properties of soil

Some important physical properties of soils are texture, structure, pore space, bulk density, colour consistence, aeration, water and temperature. They are briefly discussed belwo.

1.5.1.1 Soil texture

The relative proportions of various size groups namely sand, silt and clay in soil is referred to as soil texture. It is an important characteristic because it gives a good indication of other properties such as water storage, drainage and nutrient supply. The soil particles vary in size form gravel and sand to the finest clay. The size limits to distinguish different particle groups are shown in Table 1.

Table 1. The size of different particle group

	Particle Group (Fraction)	Diameter (mm)
1.	Gravel	2.0 and more
2.	Coarse sand	2.0 to 0.2
3.	Fine sand	0.2 to 0.02
4.	Silt	0.02 to 0.002
5.	Clay	0.002 and less

Depending upon the relative proportion of the different sized fractions, the soil can be classified into different textural classes. The principal classes in the order of increasing content of finer particles (i.e. silt and clay) are sand, loamy sand, sandy loam, loam silt loam, silt, clay loam and clay. On the basis of the percentage of sand, silt and clay, the textural class of a given soil can be determined using the textural triangle shown the Figure 3.

To use the triangle, te relative percentages of sand, silt and clay must be known. For example, to find out the textural class of a soil which contains 20% clay, 20% silt and 60% sand, first draw a pencil line parallel to the base of the triangle through angle to just past 20% point. For silt, read down the right side of the triangle to just past 20% and draw another line parallel to the left hand side of the triangle. Read along the bottom of the triangle to 60% and draw a line parallel to the right hand side of the triangle. The point where all three lines cross indicates the textural class of the soil, which in this case is sandy loam.

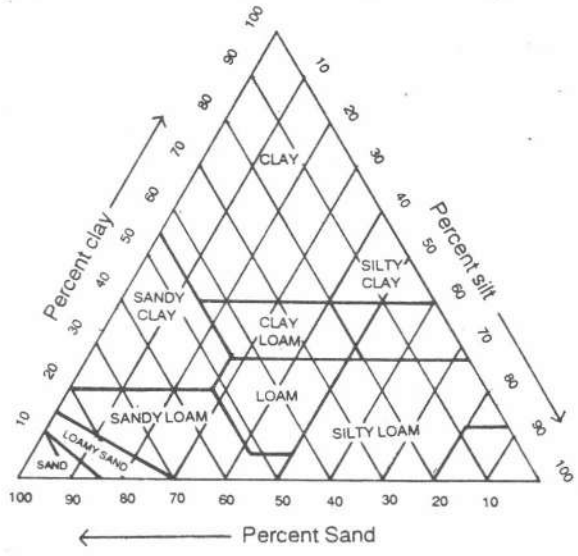


Figure 3 - **Soil textural triangle**

Soil texture can also be determined by 'feel method' which is described in the practical manual.

1.5.1.2 Soil Structure

The arrangement or grouping of particles in the soil mass is known as soil structure. The resulting structural units may be called as aggregated or peds. The aggregation of soil particle is an important factor affecting drainage, aeration and the ability of soil to release plant nutrients.

The most important types of structure are described as granular, columnar, platy angular, prismatic, and spherical. A brief description of these structural trays with schematic drawings is given below:

1. **Plate like - Platy**

   These are horizontally shaped aggregates. May occur in any part of profile.

2. **Prism-like**

   These are characterized by vertically oriented aggregates or pillars - They are found in sub soils columnar

   Prismatic

   When the tops of aggregates are flat or plane, it is called prismatic.

3. **Block like**

   Here the aggregates have been reduced to blocks, that they fit together like three dimensional blocks. They are common in B horizons.

   Blocky

   Blocky aggregates have fattened faces and mostly corners are sharp.

Subangular blocky

They have mixed rounded and flattened faces.

4. **Spheroidal**

Characteristics of A horizons. Commonly found together and sub humind region.

Granular

Granular aggregates are non-porous.

Crumbs

Crumbs are porous peds similar in appearance to crumbs of bread.

Factors affecting soil structure

- Soil texture
- Organic matter
- System of soil management
- Activities of soil organisms
- Soil moisture
- Cations like sodium, potassium and calcium

1.5.1.3 Soil Pore space

The pore space of a soil is that portion occupied by air and water. The amount of this pore space is determined largely by the arrangement of the solid particle.

Depending upon the moisture condition and drainage characteristics of the soils, the pore space will be occupied by air and water, which is essential for crop growth. Two types of individual pore space in general occur in soils, namely macro pores and micro pores The macro pores (30 µm diameter) are usually air filled and don't contain water except when the soil is saturated or draining. The micropores (<30µm diameter) include those which are responsible for storing water in the soil.

1.5.1.4 Soil Bulk density

The density of soil is an expression of how loose or tight a soil is. It includes both the solid particles and the pore spaces among them. Bulk density is defined as the mass (weight) of a unit volume of dry soil. The bulk density of uncultivated soil usually ranges from 1.0 to 1.6 g/cm3. The variation is largely due to differences in total pore space. Clay soil have bulk density ranging from 1.10 to 1.40 g/cm3.

Loams, sandy loams, and sand have bulk densities ranging from 1.20 to 1.80 g/cm3.

1.5.1.5 Soil Colour

The colour of a soil is an important indicator of certain physical and chemical characteristics. Soil colour is due to two important factors (i) humus chemical (decomposed organic matter), content and (ii) the chemical nature of the iron

compounds present in soil. The soils vary in colour from black, darkbrown, red, reddish brown, yellow, bluish green, greenish gray and gray to white. Dark brown to black colour of soil indicates a high content of humus. The red or brown colour is closely associated with good aeration and drainage, and indicates the presence of ferrous compounds.

1.5.1.6 Soil Consistency

Soil consistence is a term used to describe the physical condition of a soil at various moisture contents. Terms that are commonly used to describe soil consistency are as follows:

Wet soil	:	non sticky, sticky, non plastic, plastic
Moist soil	:	loose, friable, firm
Dry soil	:	loose,soft, hard

1.5.1.7 Soil Aeration

It has already been mentioned that about 25% of the soil volume is occupied by air. The non-capillary pore space generally constitutes the air space of soil. Like atmospheric air, the soil air is composed largely of nitrogen, oxygen and more carbon dioxide. Soil aeration is very important for root growth and microbial activities.

1.5.1.8 Soil Water

Soil temperature affects seed germination, root growth and microbial activity. Direct radiation from the sun, the heat generated by the decomposition of organic matter in the soil, and the heat from the earth's interior are the chief sources of soil temperature. The temperature of the soil is influenced by its colour, texture, slope and water content. Dark colored soil absorb more heat than those of lighter colour.

1.5.1.9 Soil Temperature

Soil temperature affects seed germination, root growth and microbial activity. Direct radiation from the sun, the heat generated by decomposition of organic matter in the soil, and the heat from the earth's interior are the chief sources of soil temperature. The temperature of the soil is influenced by its colour, texture, slope and water content. Dark colored soils absorb more heat than those of lighter colour.

INTEXT QUESTIONS 1.2

A. Fill up the blanks

1. The relative proportion of various size groups in soil is referred to.....
2. The soil particle having a diameter of 0.002 mm is called as.....
3. The arrangement of grouping of soil particles is known as.....
4. The portion occupied by air and water in soil is termed .....
5. Among the physical properties of soil.....affects seed germination and microbial activity.

B. State true or false

1. Sandy soils are having higher bulk density than clay soil
2. Dark colour of soil is an indicator of high content of mineral.
3. Capillary pore space generally constitutes the air space of soil.
4. Soil texture is more important than soil structure in influencing drainage and water.
5. Cations like sodium and calcium affect soil structure.

1.5.2 Chemical Properties of Soil

Soil differ very much in their mineralogical and chemical composition due to the nature of rocks from which they are formed. These properties of soil are very important. Now some important chemical properties are discussed in this section.

1.5.2.1 Soil reaction or PH

The term 'soil reaction' refers to the concentration of hydrogen ions (H^+) and hydroxyl ions (OH^-) in the soil solution. It is the soil chemical property most commonly measured by farmers. A soil is said to be acidic when the concentration of H^+ is higher than the concentration of OH^- (fig 4). When the concentration of hydroxyl ions is in excess of hydrogen ions, the soil is basic (alkaline) in reaction (Fig 4). A soil is neutral when the concentration of H^+ ions and OH^- ions in the soil solution are equal (Fig. 4).

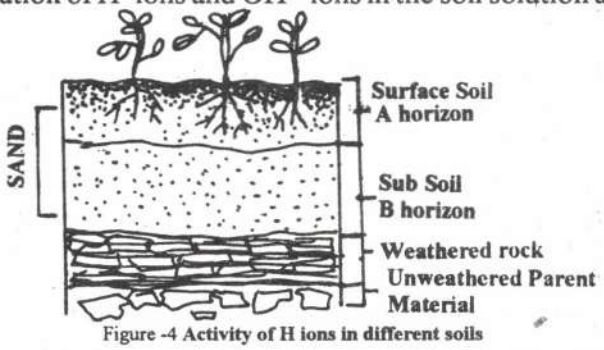


Figure -4 Activity of H ions in different soils

The degree of soil acidity or alkalinity is expressed by means of the pH scale which extends from 1 to 14. The pH is defined as the negative logarithms of hydrogen ion concentration.

The pH rating of soils is given in Table 2.

Table 2. pH rating of soil

pH range	Soil rating
7.1 - 8.5	alkaline
7.0	neutral
6.6 - 7.0	near neutral
6.0 - 6.5	slightly acidic
5.3 - 5.9	moderately acidic

4.5 - 5.2	strongly acidic
4.5	extremely acidic

1.5.2.2 Soil Collides

The colloidal particles are minute in size mostly less than 1/1000 of a mm. The colloidal fraction of soil consists of two groups:

i) Inorganic colloids - eg. clay

ii) Organic compounds - eg. humus

a) Inorganic colloids

It is also referred to as clay minerals. It consists of (a) silicate clay minerals and (b) hydrous oxide clays.

b) Silicate clay

The common clays present in the soils are mostly silicate clays. There are two types of silicate clays namely 1:1 clay mineral and 2:1 clay mineral.

1.1 Clay mineral

Example for 1:1 clay mineral is kaolinite. They have one layer of silica and one layer of alumina which are bonded together as shown in figure 5. They are described as non-expanding.

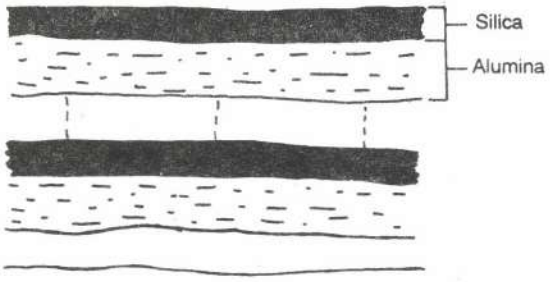


Figure-5 **Structure of 1:1 Clay mineral Kaolinite**

2.1 Clay mineral

Here the crystalline unit is made up of three layers, one layer of alumina molecules is sandwiched between two silica layers as shown in figure 6. Examples for 2:1 clay mineral are montmorillonite and illite.

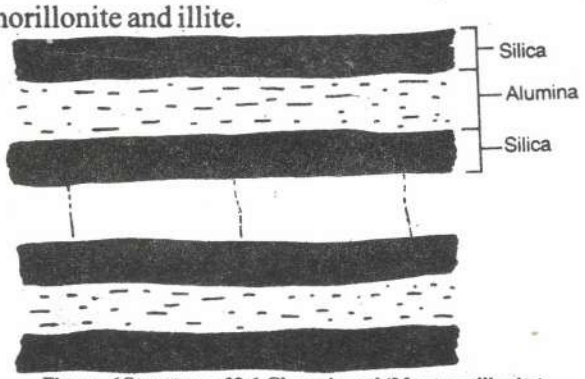


Figure -6 **Structure of 2:1 Clay mineral (Montmorillonite)**

220

(b) Organic soil colloids

Humus fraction is termed as organic soil colloids. Humus is regarded as a temporary end-product of microbial decomposition of plant and animal residues. Humus is an amorphous, dark-drown to black material, insoluble in water but soluble in dilute alkali solution.

1.5.2.3 Electrical conductivity

The electrical conductivity measurement gives the total amount of soluble salts present in the soil and is generally expressed as millimhos/cm. As the amount of the soluble salts in a solution increases the electrical conductivity also increase. This electrical conductivity is measured in terms of the resistance offered to the flow of current using a conductivity bridge.

1.5.2.4 Cataion Exchange Capacity (CEC)

The cation exchange capacity of a soil is simply a quantitative measure of the soils ability to hold exchangeable cations. It indicates the quantity of negative charge present per unit mass of soil. It is often defined as the sum of exchangeable cations adsorbed per unit weight of soil. Generally it is measured in milliquivalents per 100 g of soil (m.e./100g). Cation exchange is a critical factor in soil fertility from two important stand points. Firstly, it affects the total amount of nutrients available to plants as exchangeable cations. Secondly it influeces the degree to which the exchange complex is saturated with basic ions as opposed to hydrogen ions. Low exchange capacity implies that:

a) the soil is low in exchangeable plant nutrients.

b) conventional fertilizer practices could lead to nutrient imbalance.

c) nutrients such as K Mg and NH4 can only be held weakly by the soil and so may easily leachout.

Soil high in organic matter or 2:1 type clays (vermiculite & monotomorillonite) have a high CEC.

1.5.2.5 Anion exchange

Majority of the sites in soil clay minerals and humus are negativey charged. However, some positively charged sites may also be present. These colloids attract and exchange soluble anions. Thus these soils exhibit anion exchange instead of cation exchange. Soluble anions such as nitrates, chlorides, and sulphates are normally held and exchanged in this manner

1.5.2.6 Organic matter in the soil

Organic matter in the soil is mixture of materials consists of plant and animal remains, living and dead microorganisms and the products of decay which has taken place over months or even years. Humus is a term used to refer to the well decomposed, stable organic matter in the soil. Litters is the relatively undecomposed organic matter.

Organic matter contains large number of complex materials including carbohydrates (starches, sugars and cellulos), lignin (wood), proteins, mineral (Ca, Fe, P, S, Mg & K), fats and resins. Organic matter plays very important role in soil fertility. Some important functions of organic matter are:

1. Supplies food for micro and macro organism.
2. provides all essential plant nutrients.
3. improves the soil texture, soil tilth and pore spaces.
4. Organic acids released during decomposition of organic matter aid in the weathering process.

1.4.3 Biological properties of Soil

It refer to biological conditions of soil.

1.5.3.1 Soil Organisms

A large number of different forms of organism live in the soil, as indicated below:

SOIL ORGANISM

Macro Organism	**Micro Organism**	
Earthworm		
Termites	**Micro flora**	**Micro fauna**
Insects	Bacteria	Protozoa
	Actinomycetes	Nematodes
	Fungi, Algae	

Microorganisms play very important role in various soil processes as discussed below:

1.5.3.2 Mineralization

It is a bio-chemical process which describes a whole series of reactions by which organic matter is decomposed by microorganisms to release simple inorganic ions.

1.5.3.3 Nitrification

The ammonium produced by the decomposition of proteins in the soil is immediately acted upon by specific groups of bacteria called 'Nitrosomonas' and converted into nitrites. The nitrites are in turn acted upon by another group of bacteria, known as Nitrobacter and convrted into nitrates. Mineralization and nitrification processes are very important as they affect the plant availability of nitrogen in soil.

1.5.3.4 Nitrogen fixation

Atmospheric nitrogen is changed into nitrogenous compounds in the soil. This process is accomplished by bacteria which are either symbiotic or non-symbiotic.

Rhizobium	(symbiotic bacteria)
Azotobacter sp.	(Non-symbiotic bacteria)
Clostridiumsp.	

Some algae also assist in fixing atmospheric nitrogen, particularly in moist hot climates. e.g. Blue-green algale.

1.5.3.5 Denitrification

There are bacteria that live in the soil and reduce nitrogen compounds in the soil and release nitrogen as gas e.g. Pseudomonas denitrificans.

1.5.3.6 Phosphorus mobilization

Some bacteria convert insoluble phosphorus into soluble phosphorus and favour plant uptake of phosphorus. e.g. Phosphobacterium

INTEXT QUESTIONS 1.3

A. Choose the correct answer.

1. In acidic soil
   (a) hydroxyl ions is higher
   (b) hydrogen ions is lower
   (c) hydrogen ions is higher
   (d) hydroxyl ions and hydrogen ions are equal.
2. .....is a 2:1 type clay mineral.
   (a) Montomorillonite
   (b) Kaolinite
   (c) hydrous oxide clay
   (d) clay
3. .....is an organic soil collide.
   (a) illite
   (b) rocks
   (c) humus
   (d) clay
4. .....is generally a non-expanding type clay mineral
   (a) humus
   (b) organic matter
   (c) illite
   (d) kaolinite

5. Which one involves in the non-symbiotic nitrogen fixation.

(a) Pseudomonas sp.

(b) Azotobacter sp.

(c) Nitrosomonas sp.

(d) Rhizobium sp.

(B) Match the following:

1.	Hydrous oxide clays	a)	High CEC
2.	Total soluble salts	b)	Denitrification
3.	Organic matter	c)	Inorganic collide
4.	Earthworm	d)	Microorganism
5.	Pseudomonas sp.	e)	Electrical conductivity
6.	Protozoa	f)	Macroorganism

WHAT YOU HAVE LEARNT

Soil is natural body composed of mineral, air, water and organic matter. Soils are formed by the disintegration and decomposition of rocks which form parent materials.

Depending upon the minerals and chemical composition of rocks, the soils will have their properties. Soil formation is a function of climate, organisms, relief, parent material and time.

The characteristics of soils are studies by examining soil profile, which is a vertical cross section of soil having distinguished layers.

There are about eight major soil groups occur in India. Alluvial soil occupies the largest area followed by black soil.

Depending upon the effect of various factors and processes of soil formation, soils have different physical and chemical and biological properties.

Among the various physical properties of soil, texture, structure, pore space, colours aeration, water and temperature are important.

Soil pH or the concentration of hydrogen and hydroxyl ions largely decides behaviour of soil.

Soil consists of two types of colloids namely organic and inorganic colloids. In most soil, silicate clay minerals are predominantly present.

Cation and anion exchange capacities of soil play critical role in soil fertility. Macro and micro organisms influence various biological processes of soil and release the available nutrients for crop growth.

GLOSSARY

Soil	:	Natural body loose, unconsolidated material which constitutes a thin layer of earth's crust.
Granite	:	A common igneous rock found in India.
Clay soil	:	The finest textured soil, clay particles are less than 0.002 mm in diameter.
Soil colloid	:	Inorganic or organic matter with a very small particle size.
Humus	:	Well decomposed organic matter.
Cation exchange capacity	:	The total of exchangeable cations, that a soil can absorb.
pH	:	Negative logarithm of hydrogen ion activity
Weathering	:	Process of disintegration and decomposition of parent rock material.
Soil profile	:	A vertical cross-section of soil
Solum	:	The horizons above the parent material (rock)
Soil texture	:	The relative proprtions of various size groups is referred as soil texture
Soil structure	:	The arrangement of particles in soil mass known as soil structure
Acidic soil	:	Where the activity of hydrogen ions is higher than hydorxyl ion (pH : 6.)
Neutral soil	:	Where the activity of H^+ and OH^- ions are equal (pH = 7.0)
Alkaline soil	:	Where the activity of OH^- ions is higher than H^+ ions (>pH : 7.0)
Organic matter	:	It is a mixture of materials consist of plant and animal remains, living and dead organisms and the products of decay.

TERMINAL QUESTIONS

1. What are the components of soil? Briefly describe them.
2. What are the types of rocks found in India? Give examples.
3. Describe how soils are formed. What are the factors affecting the soil formation.
4. Distinguish between?

a) Physical weathering and chemical weathering.

b) Soil texture and soil structure

c) Cation exchange capacity and anion exchange capacity

d) 2:1 clay mineral and 1:1 clay mineral

5. Give brief account of various groups of soil found in India.

6. What is soil pH?

7. Find out the textural class of the following soil

a) Clay 55%, Sand 20% silt 25%

b) Clay 10%, Sand 50% Silt 40%

8. Define the following terms

a) Soil bulk density

b) Pore space

9. Give examples for the following

a) Microorganisms involved in Nitrogen fixation

b) Microorganism involved in Phosphorus mobilization

c) Silicate clay minerals

d) Processes of chemical weathering Sedimentary rocks

e) Sedimentary rocks

f) Rock minerals

10. What is the importance of organic matter?

KEY TO INTEXT QUESTIONS

INTEXT QUESTIONS 1.1

1.1.A

1. Soil
2. 255, 45%
3. disintegration, decomposition
4. igneous, sedimentary, metamorphic
5. Feldspars
6. Climate
8. Mineral content of parent material
9. soil profile solum

10. alluvial black soil

1.1 B

1. (c)
2. (d)
3. (c)
4. (d)
5. (a) Flase, (b) True, (c) True, (d) False, (e) False

INTEXT QUESTIONS 1.2

1.2 A

1. Soil texture
2. Clay
3. Soil structure
4. Pore space
5. Soil temperature

1.2 B

1. True
2. False
3. False
4. False
5. True

INTEXT QUESTIONS 1.3

1.3 A

1. (c)
2. (a)
3. (c)
4. (d)
5. (b)

1.3 B

1. (c)
2. (e)

3. (e)
4 (f)
5 (b)
6. (d)

Module - 2

PHYSICAL PROBLEMS

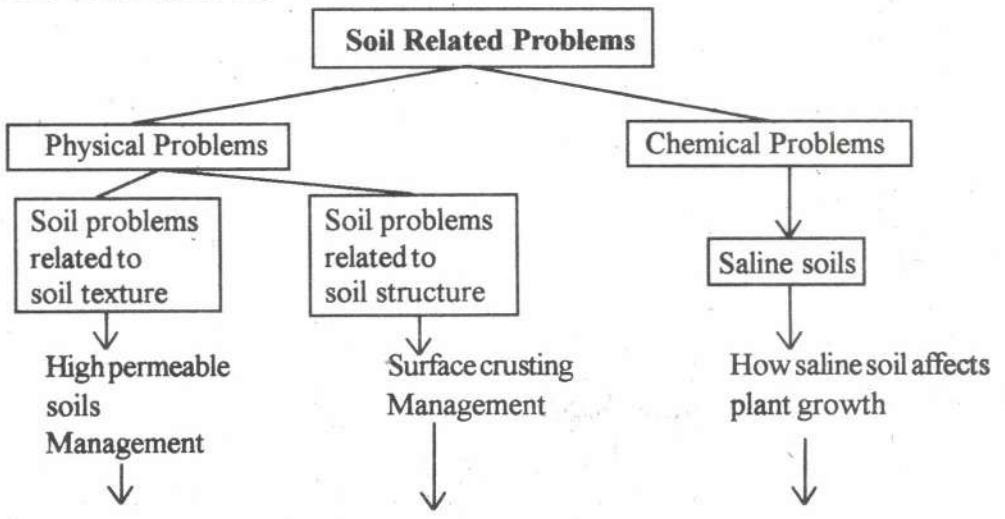
INTRODUCTION

Soil is the media for plant growth. It supplies water, nutrients and provides an charge to the growing plants. A good soil is one which provides a favorable environment for the plants. The conditions which are favorable for the plants are,

- Optimum physical environment
- Balanced nutrient supply
- Weed disease and pathogen free soil conditions.

Soils which lack one or more of the above qualities are termed problem soils.

KEY CONCEPTS



Low permeable soils
Management

Sub-soil hardening
Management
↓
Fluffy paddy soils
Management

Source of salts
↓
Characteristics of saline soils
↓
Management
↓
Sodic soils
↓
Reclamation and Management
↓
Acid soils
↓
Effect on crop growth
↓
Management

OBJECTIVES

After studying this lesson, you will be able to :

- differentiate a normal soil and a problem soil;
- identify the problems related to soil physical conditions;
- diagnose and suggest suitable alternitive measures for the above problems;

You have learnt in your earlier portions that soil is made up of mineral matter and organic matter. The mineral matter is constituted by different sized soil particles like sand, silt and clay. Depending upon the proportion of these fractions, the physical condition of the soil varies. The proper arrangement of the soil particles into aggregates of different size and stability is the next important criteria to termine the soils into a normal soil or problem soil. In general, the problems related to the physical environment of the soil are either by the improper proportion of soil particles (soil texture related problems) or by poor aggregation (soil structure related problems).

2.1.1 Soil problems related to soil texture

The sand, silt and clay constitute a major component of the soil mineral matter. An optimum soil texture is the one with almost equal amount of these fraction. This facilitates proper aeration, optimum water holding capacity with a good tilth for the growing seeds and penetrating roots. The following are some of the problems that occur due to improper proportion of the soil particles.

2.1.1.1 High permeable soils

High permeable soils are soils having dominant proportions of sand resulting in greater

proportion of macro pores. This results in the easy percolation of water and nutrients beyond the root zone depth. The characteristics of such soils are

- Dominant amounts of sand upto about 70 per cent
- High infiltration rate of the soil
- High permeability
- Poor nutrient retention
- Low available water status
- High bulk density

Management

These soils can be managed very effectively and brought to the orginal level of production by adopting the following strategies.

- Provision of sub surface soil barriers like asphalt,bentonite clay etc., but it is an expensive method.
- Compacting the soil by rolling a 400 kg stone roller for 8-10 times across the field.
- Mixing the soil with fine textured clay soil or silt deposits.It can be done by adding clay soils upto 1 percent of soil weight.
- Application of large quantities of organic manures like farm yard manure, compost etc.

2.1.1.2 Low permeable soils

Low permeable soils are characterised by the presence of high proportions of clay (>50%), resulting in poor mobility of water and nutrients. The properties of these soils are

- Low infiltration rate
- Low percolation of water
- High nutrient fixation resulting in the poor nutrient availability to plants.
- Poor aeration due to predominant micropores
- Poor gaseous exchange between soil and atmosphere
- Poor drainage resulting in water logging

Management

The management of such soils can be done by adopting the following strategies.

- Mixing the soil with river sand upto 100 t/ha level depending upon the severity of the problem.
- Adopting ridges and furrows with intersectional drainage channels.

- Deep ploughing to loosen the soil and to increase infiltration and percolation.
- Application of liberal quantities of organic manures

2.1.2 Soil problems relating to soil structure

Under field situations, soil particles do not exist as single grain. They usually adhere together and form soil aggregates in optimum size and stability is very important for a favourable plant growth. Lack of aggregates or presence of aggregates of bigger size and high stability results in problems.

2.1.2.1 Surface Crusting

Surface crusting occurs in soils having weakly cemented aggregates, which break into single grains due to the impact of rain drops. The dispersed soil particles settle at different velocities with clay at the top of the soil surface. On drying the clay particles form crust. These soils are characterised by

- Poor organic matter content
- Reduced soil aeration
- Poor gaseous exchange between soil and atmosphere.

Management

The management of surface crusted soils can be done by the following methods.

- The impact of rain drop is reduced by surface mulching by polythene mulch, crop residue mulch etc.,
- Improving the aggregation by addition of organic manure, gypsum etc.,

2.1.2.2 Sub soil hardening

Sub soil hardening is a process by which the sub soil becomes hard due to the accumulation of fine clay particles and organic matter through the percolating water. Another possibility is due to the repeated cultivation which results in the sub soil compaction. Such soils are characterised by

- Sub soil having high bulk density of above 1.6 to 1.7 $Mg.m^{-1}$
- Reduced percolation

Management

Soils with sub soil hard pan at shallow depth can be managed by

- Deep ploughing
- Cutting the hard pan by a special type of plough called "chisel plough" by ploughing at an interval of 0.5 metre on both directions of the field.

2.1.2.3 Fluffy paddy soils

Fluffy paddy soils are paddy soils which are very soft due to the increased addition of crop residues. This results in the sinking of labour, animals and machinery making the cultivation operations more difficult.

Management

These soils are reclaimed by rolling a heavy roller of 400 kg 8-10 times across the field, at optimum soil mixture conditions. This can be done once in 2-3 years.

INTEXT QUESTIONS 2.1

(A) Fill up the blanks

1. The problems relating to soils texture are _____ and _____.
2. High permeable soils are dominated by the _____ fractions.
3. Low permeable soils are associated with _____ infiltration rate and _____ percolation rate.
4. Poor aeration is associated with _____ and _____ soils.
5. Weakly cemented aggregates are responsible for _____ _____ problem.

(B) State whether the following statements are true or False.

1. High permeable soils are coarse textured.
2. Low permeable soils are usually well drained.
3. Mulching helps in the prevention of surface crusting by increasing the water stable aggregates.

2.2 CHEMICAL PROBLEMS

The availability and absorption of nutrients by the plants are mostly governed by the soil reaction (pH) and electrolyte concentration in the soil solution (measured as electrical conductivity). In general, soils falling in the pH range of 6.5-7.5 are having the nutrient supply in a balanced manner. Hence such soils which do not possess an optimum range of pH and electrolyte concentration not exceeding a certain limit poses problems.

2.2.1 Saline soils

Saline soils are defined as those soils having considerable amounts of soluble salts in the soil solution to interfere plant growth but not having enough quantities of exchangeable sodium to interfere the soil properties. Technically, saline soils are those soils having an electrolyte concentration of more than 4 $ds.m^{-1}$, pH of <8.5 and exchangeable sodium percentage (Ratio of exchangeable sodium to cation exchange capacity expressed as percentage) not exceeding 15 percent.

How saline soils affects crop growth?

Plants grow in the soil by absorbing water and nutrients. Absorption of solution is governed by a process called Osmosis, which is the movement of solution from a lower concentration (soil solution) to higher centration (Root sap) through a semi permeable

membrane (root epidermis). In saline soils, the concentration of salts in the soil solution is higher to the extent that root sap exudates into the soil resulting in the drying up and wilting of the plants.

Sources of salts

The higher salt concentration in the saline soils are through various sources. They are

- By weathering of parent rock (Geological)
- Increased evapotranspiration than precipitation resulting in the movement of salts to the root zone (climatological)
- By leaching or transport of salts by surface or subsurface movement of water (hydrological)
- Addition of water through the irrigation water (ground water)
- Capillary rise of water along with salts from the lower horizons of the profile to the surface soil (Secondary salinization)

Characteristics of saline soils

The saline soils are characterised by

- White salt deposit on the surface of the soil during the dry periods of the year.
- The presence of salt bushes
- Failure of seed germination
- Patchy stunted growth

Management

Saline soils can be managed by

- Leaching the salts by providing drainage facilities, either surface or sub-surface.
- Increasing the frequency of irrigation i.e. irrigating more often with less water.
- Adopting the modern irrigation methods like drip and sprinkler which keep the surface soil always moist.
- Adoption of irrigation methods like ridges and furrows, broad bed furrows, alternate furrow and skip furrow irrigation to facilitate the accumulation of salts in the zone away from the roots.

Ridges and Furrows

- Mixing good quality water with saline water.
- Choosing saline tolerant/resistant varieties like ragi, cotton, sunflower etc., and avoiding crops which are sensitive like pulses and groundnut.

2.2.2 Sodic soils and saline sodic soils

Sodic soils are defined as those soils containing appreciable amounts of exchangeable sodium to interfere crop growth by poor soil conditions. Saline sodic soils are those soils which are containing higher amounts of soluble salts to interfere crop growth and appreciable amounts of sodium to alter the soil properties. Technically,sodic soils have the exchangeable sodium percentage exceeding 15 percent, pH more than 8.5, but electrical conductivity below 4 $ds.m^{-1}$, saline sodic soils are characterised by both sodicity as well as salinity.

The characteristic of sodic soils are

- Black encrustation on the surface soil.
- Highly dispersed under wet conditions and very hard during dry conditions.
- Compact subsurface horizon.
- Poor, stunted patchy growth.
- Low infiltration, poor percolation and poor aeration.
- Toxicity of nutrients like sodium, boron and molybdenum.
- Deficiency of nutrients like calcium and mangnesium.

Reclamation and management

The reclamation principle involves

- Replacing the excess sodium from the clay complex.
- Removal of sodium from the root zone.

The management practices are

- Application of amendments like gypsum,pyrites etc., to remove sodium from exchange complex
- Draining the replaced sodium by providing drainage facililties.
- Application of organic manures like farm yard manure, compost, green manure etc.,
- Growing crops which are tolerant/resistant to sodicity.

2.2.3 Acid Soils

Acids soils are defined as those soils having higher concentration of hydrogen or aluminum resulting in the lower pH. This reduces the availability of some of the essential nutrient elements like calcium, magnesium, nitrogen, phosphorus, potas-

sium, molybdenum etc., and toxicity of some of the elements like iron, manganese, zinc, copper, cobalt etc.,

How acid soils are formed?

Acid soils are formed due to the following reasons.

- Leaching of bases like calcium and magnesium in high rainfall areas.
- Formation of soil from acidic parent materials.
- Continuous application of acid producing fertilizers
- Weathering of alumina silicate minerals.
- Hydrolysis of the hydrous oxides of iron and aluminum.
- Soil forming processes like laterization.

Effect of acidity on soil and plant growth

The effect of acidity on soil and plant growth are as follows:

- High dispersion of soil particles resulting in the chemically unstable soils.
- Reduced permeability of the cell membrane
- Reduced uptake of water and nutrients like nitrate.
- Toxicity of elements like iron, aluminum, and Magnesium.
- Deficiency of nutrients like calcium, potassium, phosphorus,molybdenum etc.,

Management of acid soils

Reclamation of acid soils is by raising the pH of the soil to near neutrality (6.5-7.5). The common amendments are lime (calcium carbonate),dolomite (calcium magnesium carbonate), calcium hydroxide,magnesium hydroxide etc.,

INTEXT QUESTIONS 2.2

2.2. Choose the right answer

1. Saline soils have
   a. Higher sodium content in soil solution
   b. Higher soluble salts in solution
   c. Higher exchangeable sodium
   d. None of the above
2. Saline soils can be reclaimed by
   a. Leaching
   b. Application of amendments
   c. Application of amendments and leaching

d. None of the above

3. Sodic soils are defined as those soils having
   a. pH < 8.5, EC > 4 ds.m^{-1} and ESP < 15%
   b. pH > 8.5, EC > 4 ds.m^{-1} and ESP > 15%
   c. pH > 8.5, EC < 4 ds.m^{-1} and ESP > 15%
   d. pH < 8.5, EC < 4 ds.m^{-1} and ESP < 15%
4. Saline sodic soils are characterised by
   a. Higher soluble salts and sodium in exchange complex.
   b. High soluble salt and low exchangeable sodium
   c. Low soluble salt and low exchangeable sodium
   d. Low soluble salt and high exchangeable sodium
5. Acid soils can be reclaimed by
   a. Application of lime
   b. Application of gypsum
   c. Leaching of acidity
   d. By all the above

WHAT YOU HAVE LEARNT

A normal soil is one with optimum physical environment, neutral pH, low electrical conductivity, good aeration, drainage,optimum cation exchange capacity, moderate water holding capacity etc., problem soils lack one or more of the above properties.

The problems related to soil texture are high permeable and low permeable soils. High permeable soils can be managed by compaction and application of liberal quantities of organic manures and clay soils.

Low permeable soils can be remedied by deep tillage and sand addition. Surface crusting problem can be managed by mulching and gypsum application.

Sub-soil hard pan can be opened by chiseling.

The reclamation of saline soils are by leaching of excess salts along with management techniques.

The sodic soils are characterised by high exchangeable sodium in clay complex.

The reclamation of sodic soil is done by application of calcium amendments and leaching of removed sodium.

Acid soils are soils having higher amounts of hydrogen and aluminium resulting in low pH values

The acid soils can be made productive by application of lime materials like calcium carbonate or calcium magnesium carbonate.

Terms you must know

High permeable soils	-	Soils with predominant amounts of sand fraction resulting in high infiltration rate and percolation
Low permeable soils	-	Soils with higher clay content thus preventing the water and nutrient movement
Surface crusting	-	A soil problem occurring due to the impact of rain drop on the less stable soil aggregates
Sub soil hard pan soil	-	Soils with dense sub soil due to the accumulation of clay, organic matter and sesquioxides
Fluffy paddy soils	-	Soils which are soft resulting in sinking of animals, machinery, labour etc.
Saline soils	-	Soils with appreciable amounts of soluble salts to interfere with crop growth
sodic soils	-	Soils with greater amounts of sodium in the exchange complex
Saline sodic soils	-	Soils with both higher salt concentration and greater exchangeable sodium content
Acid soils	-	Soil with higher amount of hydrogen and aluminum resulting in low acidity

Terminal Questions

1. Differentiate between normal and a problem soils.
2. What are the problems related to soil physical properties ?
3. How do you manage the soils with high or low permeability ?
4. What is surface crusting ? How it can be prevented ?
5. How to increase the productivity of soils with sub soil hard pan
6. List the management strategies for saline soils?
7. What are the characteristics of acid soils ?

KEY TO INTEXT QUESTIONS

Intext Question 2.1

A. 1) High permeable soils and low permeable soils

2) Sand

3) Poor and low

4) Low permeable soils and fluffy paddy soils

5) Surface crusting

B 1) True

2) False

3) False

INTEXT QUESTION 2.2

(1) c (2) a (3) c (4) a (5) a

Module -3

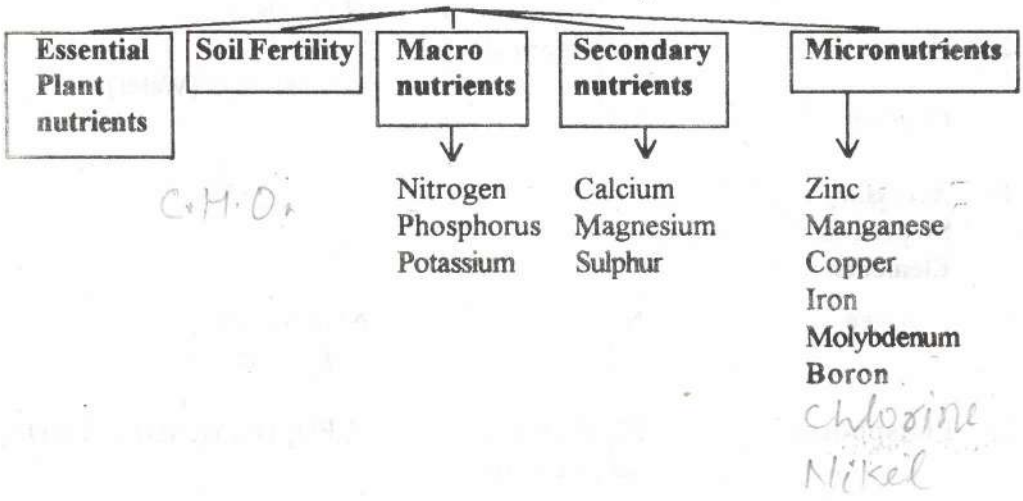
ESSENTIAL PLANT NUTRIENTS

INTRODUCTION

Plants require a number of nutrient elements for their growth and development. Not all the elements present in the plants are essential; only about seventeen elements are found essential for plant growth. The amounts of available essential plant nutrients in the soil are one measure of soil fertility. It is very important to learn about the plant nutrients, their nature and their specific role in plant growth, so that they can be efficiently managed. This lesson aims to provide a basic information about various plant nutrient elements and their functions in plant metabolism.

KEY CONCEPT

Soil Nutrients and their major role



OBJECTIVES

After studying this lesson you will be able to

- classify the nutrient elements based on their relative importance in plant nutrition;
- describe the important functions of various nutrient elements in plant growth;
- state the forms and sources of plant nutrients;
- identify the deficiency symptoms of different nutrients in plants

Essential nutrients are defined as those which are required for the normal life cycle of the plants. Professor D.I. Argon (1954) formulated certain criteria for the essential elements. Accordingly, an element is essential if

(i) a deficiency of the particular elements makes it impossible for the plant to grow normally or complete its life cycle;

(ii) such a deficiency is specific to the element and can be prevented or corrected only by supplying this element;

(iii) this element is dir. :tly involved in the plant metabolism.

Based on their functions the plant nutrient elements are classified into 4 groups. The nutrient elements and the forms in which they are absorbed by plants are given in Table 1.

Table 1: Classification of essential nutrients and the forms in which they are absorbed by plants

Element		Symbol		Form in which taken up by the plant
I	**Structural Elements**			
1.	Carbon	C	Basic nutrients	Carbondioxide (Co_2), HCO_3
				H_2O (Water)
2.	Hydrogen	H		
		O		O_2 (air), H_2O (Water)
3.	Oxygen			
II	**Accessary Structural Elements**			
1.	Nitrogen	N	Macro nutrients	NO_3(nitrate) NH_4 (ammonium)
2.	Phosphorus	P		H_2PO_4 (Phosphates) HPO^{-2}_4

Element	Symbol		Form in which taken up by the plant
3. Sulphur	S*		SO^{-2}_4(sulphate)
III Regulators and Carriers			
1. Potassium	K	Macro	K^{1+}(Potassium ion)
2. Calcium	Ca*	nutrients	Ca^{2+}(Calcium ion)
3. Magnesium	Mg*		Mg^{2+}(Magnesiumion)
IV Catalyst & Activators			
1. Iron	Fe		Fe^{2+} (Ferrous ion) Fe^{3-} (Ferrie ion)
2. Manganese	Mn		Mn^{2+} (Manganese ion)
3. Zinc Zn			Zn^{2+} (Zinc ion)
4. Copper	Cu	Micro nutrients	Cu^{2+} (Coppers ion)
5. Boron	B		BO^{3}_4- (Borate)
6. Molybdenum	Mo		MOO^{2-}_4-(Molybdate)
7. Chlorine	C1		Cl^{-1} (Chloride)
8. Cobalt	Co		Co^{2+} (Cobalt)

* also classified as secondary nutrients.

Most of the nutrients listed in Table 1 are obtained from the soil, where they are taken up by plant roots from the soil solution. The carbon, hydrogen and oxygen present in plants are obtained from carbondioxide and water.

Nitrogen, Phosphorus and potassium are used in relatively large amounts and are called as Macro nutrients. Calcium Magnesium and sulphur are called as secondary nutrients, as and when other fertilizers are added these nutrients are also supplied (eg. Single superphosphate supplies calcium, sulphur besides phosphorus).

Other nutrients like iron, zinc,manganes, copper, molybdenum, boron are needed only in small amounts and are called as micronutrients or trace elements.

3.2 SOIL FERTILITY

Nutrients are present in the soil in varying quantities. The nutrient supplying capacity of a soil for plant growth is a measure of its fertility. If the concentration of a particular nutrient in soil is very low, the soil is said to be deficient and therefore

a deficiency of that nutrient occurs and plant growth is restricted. Likewise, if the concentration of that nutrient is too high, toxicity occurs and plant growth is similarly affected.

The continuous farming has diminished the inherent fertility of soil. Our Indian soils are very low to low in available nitrogen (sandy and red soils) with the exception of hill soils (lacterite and lateritic) and part of dialytic-alluvial soils. Most soils are low to medium in available phosphorus. With regard to available potassium, approximately 20% of the soils are low (sandy and red soils), 40% are medium (mixed red/black soils) and the remaining 40% are high in available potassium. Sulphur deficiency is noted in coarse textured soils particularly on soils where crops such as pulses, oil seed, legumes and forages are predominantly grown. Among the micronutrients, Zinc deficiency is most wide-spread.

Each plant nutrient plays one or more special roles in plant growth. The individual nutrient and its role in plant growth is discussed below.

3.3 MACRO (MAJOR) NUTRIENTS

3.3.1. NITROGEN

Nitrogen(N) is a very impo. ant plant nutrient. Plant require large amount of N and contain about 1 to 6% N on a dry weight basis. Nitrogen is always the nutrient in most demand but the actual amount required varies with plant species and the environment.

Functions of Nitrogen in Plants

Nitrogen is essential to many functions within the plant which are as follows:

1. Nitrogen is very important for vegetative growth and imparts green colour to the leaves.
2. It is a primary constituent of the basic amino acids which are the building blocks of protein.
3. It is essential for the synthesis of chlorophyll and enzymes.
4. It is also essential for carbohydrate utilization.

Forms of Nitrogen

Soil nitrogen is present in two major forms: They are:

(i) organic from (protein, amines, amides etc)

(ii) inorganic form

  (a) ammonium-N held by clay minerals

  (b) mineral-N forms as ammonium (NH^{+}_{4}), nitrite ($N0^{-1}_{2}$) and nitrate (NO_{3}^{-1}) in soil solution.

The majority of soil N is present in organic form (organic matter) and is unavailable to plants. These organic compounds need to be broken down by natural biological processes to produce the plant available mineral forms of ammonium and nitrate. The conversion of

organic forms (unavailable form) of N into inorganic or mineral forms (plant available form) is known as mineralization. Soil micro-organisms play very important role in N mineralization.

The microorganisms use some of the mineral N produced and incorporate it into their own bodies which is not available to plants. This process is termed as immobilization. The processes of mineralization and immobilization can occur simultaneously in soil, depending upon the C: N ratio of the organic matter and other soil environmental conditions.

Nitrification

Ammonium in soil is transformed into nitrate by several microorganisms and the process is called as nitrification. Firstly, ammonium is oxidized to nitrite (NO_2) by the nitrifying bacteria Nitrosomonas

$$2NH_4 + 30_2 \xrightarrow{\text{Nirosomonas}} 2NO_2 + 2H_2O + 2H_2 + \text{Energy}$$

Secondary nitrite is oxidized to nitrate (NO^{-1}_3) by Nitrobacter bacteria

$$2No_2 + O_2 \xrightarrow{\text{Nitrobacter}} 2NO_3 + \text{Energy}$$

Sources of Soil Nitrogen

Soil nitrogen is obtained from the following major sources.

(a) Fertilizers and manures

(b) Atmosphere

  (i) Through rainfall

  (ii) Through biological N fixation

  (both symbiotic & non-symbiotic fixation)

  (c) Mineralization of organic matter

  (d) Crop residues.

Losses of Nitrogen from soil

Nitrogen is lost (or removed) from the soil through the following processes.

(a) Crop uptake

(b) Leaching (mostly no_3 leaching)

(c) Gaseous losses

  (i) Through ammonia (NH_3) volatilization

  (ii) Through denitrification

(d) Erosion losses

(e) Immobilization

3.3.2 PHOSPHORUS

Phosphorus (P) is regarded as a key nutrient for successful growth of plants. Plants contain between 0.1 and 0.5% P in the dry matter.

Functions of Phosphorus in plants

Phosphorus has many different functions in plants and the most important ones are as follows:

1. It is essential for storage and transfer of energy.
2. It is essential for flowering, fruiting and seed formation.
3. It is required for cell division.
4. It is essential for root development and crop.
5. It plays an important role as a structural component of the cell constituents.
6. It is also essential for improvement of crop quality.

Forms of Phosphorus

Phosphorus occurs in soil both as organic and inorganic forms. About 20 to 80% of P in soils is generally present in organic forms. In most tropical soils, maintenance of soil organic matter is directly related to the maintenance of organic P. Organic P is microbially converted into the plant available form like H_2Po_4 and HPO_4, by the process of mineralization.

Most inorganic P in soils present is the calcium phosphates and the iron and aluminum phosphates. Calcium phosphates are more soluble than iron and aluminum phosphates. In calcareous and neutral soils, calcium phosphate is predominantly present, whereas in acid soils iron and aluminum phosphate are present.

Sources of Phosphorus:

Soil phosphorus is obtained from the following sources

1. Mineralization of organic matter.
2. Chemical fertillizers
3. Crop residues and manures
4. Phosphorus bearing soil minerals

3.3.3 POTASSIUM

Potassium (K) is often referred to as the third major nutrient for plant growth after N and P.

Functions of Potassium in plants

1. Potassium is essential for plant resistance to certain pests and diseases.
2. It is an activator of many enzymes.
3. It helps to regulate the opening and closing of stomat a in the leaves.

4. It is essential for photosynthesis and for starch formation.
5 It is necessary in the development of chlorophyll.
6 It is important for grain formation.
7. It helps in efficient use of water by plants.
8. It helps to prevent the lodging of plants.

Forms of Potassium

Soils generally contain large amounts of total potassium. Total potassium consists of three distinct forms in the soil as illustrated in Fig. 1.

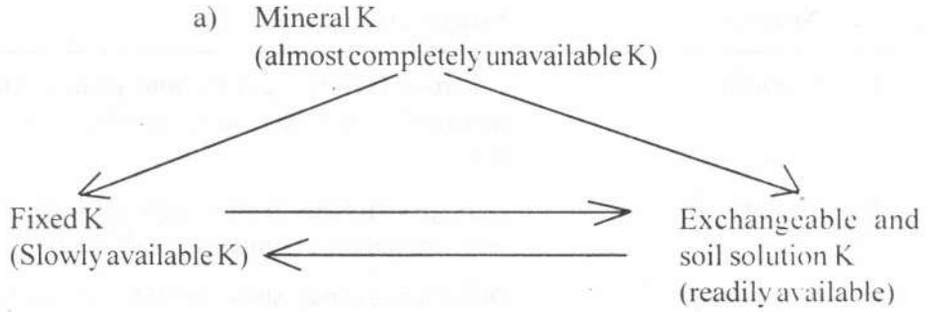


Figure 1. Forms of Soild Potassium

The vast majority of soil potassium (90-98%) is found in soil minerals, which is completely unavailable to plants. About 1 to 10% of total potassium is in fixed (non-exchangeable) form, which may be slowly available. Only about 1 to 2% of total potassium is in readily available(exchangeable) form. The slowly available K and readily available (exchangeable) K are in dynamic equilibrium in soil.

Sources of Soil Potassium

Potassium is added to the soil through

1. Chemical fertilizers
2. Weathering of K bearing soil mineral
3. Crop residues and manures

3.3.4 Important Factors Affecting the Plant Availability of Macronutrients

1. Organic matter content of soil
2. Type of clay mineral (parent material)
3. Soil pH
4. Soil moisture content
5. Soil temperature

6. Soil microorganisms

7. Soil texture

3.3.5 Deficiency Symptoms of Macronutrients

Plant develops certain characteristic symptoms when it is suffering from a particular deficiency. Table 2 presents the general description of N, P & K deficiency symptoms.

Table 2

Deficiency symptoms of N, P & K

	Nutrient	Symptoms
1.	Nitrogen	Chlorosis (yellowing) of whole plant often with reddening. Older leaves usually affected first
2.	Phosphorus	Dark green foliage, reddening or purpling of leaves or petioles (similar to cold effects)
3.	Potassium	Older leaves may show necrotic spots or marginal burn, younger leaves may develop red pigmentation or become interveinally chlorotic and show a shiny surface.

INTEXT QUESTIONS 3.1

(A) Fill in the blanks:

1. The amount of available plant nutrients in soil are one measure of _____

2. Essential elements play direct role in the _____

3. _____ and _____ are the forms of N taken up by the plants.

4. Indian soils are generally _____ in nitrogen, _____ in phosphorus and _____ in potassium

5. Approximately 1 to 10% of total potassium is in _____ form, which may be _____ available.

(B) Choose the correct answers:

1. The microbial conversion of organic form of N into inorganic form is termed as
   a) Volatilization
   b) Immobilization
   c) Mineralization
   d) Nitrification
2. The Nutrient required for disease resistance is
   a) Nitrogen
   b) Hydrogen
   c) Potassium
   d) Phosphorus
3. Plant absorbs phosphorous in the Form of
   a) $H_2PO^{-1}_4$
   b) $Ca_3(PO_4)_2$
   c) Orgamic - p
   d) Rock phosphate
4. Which is not the major source of soil potassium
   a) Chemical fertilizers
   b) Soil mineral
   c) Organic matter
   d) Crop residues and manures
5. Gaseous N is lost from the soil through
   a) Leaching
   b) Immobilization
   c) Crop uptake
   d) Denitrification

3.4. SECONDARY NUTRIENTS

3.4.1 CALCIUM

Calcium is a macronutrient and is essential for plant growth.

Functions of Calcium in plants

1. Calcium is essential for the proper growth and functioning of root tips.
2. It is an important constituent of the cell wall.
3. It is required for the transport of carbohydrates and proteins in the plants.

Form of Calcium

Calcium is found mainly in minerals such as feldspars, calcite ($CaCo_3$), dolomite ($CaCo_3$ $MgCo_3$) and apatite (Ca-phosphates). Calcium also occurs as a divalent cation (Ca_2+) in the soil solution and on the exchange sites of soil colloids.

Sources of Calcium

Calcium is commonly added as lime, gypsum and in fertilizers such as superphosphate and rock phosphate.

3.4.2 MAGNESIUM

Magnesium is also a macronutrient required by plant.

Major Functions of Magnesium in Plants

1. Magnesium is essential for photosynthesis and forms important constituent of chlorophyll molecule.

Forms and Sources of Magnesium

Magnesium is found in three forms in soil. They are:

i) Mineral magnesium (very slowly available)

ii) Exchangeable magnesium (readily available) and

iii) Soil solution magnesium (readily available).

Soil minerals such as dolomite and biotite are the major sources of magnesium in soil.

3.4.3. SULPHUR

Sulphur is required by plants in amounts similar to those of phosphorus. It is also regarded as an accessory structural element. It is very essential for all seed crops.

Major Function of Sulphur in Plants

1. Sulphur is very essential for protein synthesis.
2. It is a constituent of the amino acids (cysteine and methionine).
3. It is essential for the synthesis of enzymes and vitamins.
4. It plays an important role in root nodulation.

Forms and Sources of Sulphur

In most soil sulphur is mainly present as organic sulphur and only a small fraction is in the inorganic form. Mineralization of organic sulphur leads to the formation of inorganic sulphur as sulphates (SO^{2-}_4). Sulphate can occur in soils in three major forms:

i) as sulphate ions in the soil solution

ii) as adsorbed sulphate, and

iii) as various sulphate minerals.

Sulphur in soils is derived mainly from the soil minerals, mineralization of organic matter, fertilizers and also from atmospheric inputs like rainfall and S-containing gaseous compounds.

3.4.4 Deficiency Symptoms of Secondary Nutrients

Deficiency symptoms of calcium, magnesium and sulphur are listed in Table 3

Table 3

Deficiency Symptoms of Secondary Nutrients

	Nutrient	Deficiency Symptoms
1.	Calcium	Death of growing points, burning of tip. In fruit crops, disorders of fruits (eg. blossum- end rot in tomato)
2.	Magnesium	Marginal or interveinal chlorosis. Green area of leaf may form a 'arrow head' in woody plants. Reddening of leaf (eg. cotton)
3.	Sulphur	Chlorosis of the whole plant, younger leaves affected first.

INTEXT QUESTIONS 3.2

Say true or false

1. Magnesium is essential for the functioning of root tips.
2. Sulphur is very essential for oil seed crops.
3. Calcium is also regarded as an accessory structural element.

4. Reddening of cotton leaves is due to magnesium deficiency.
5. Calcium is found in biotite.
6. Magnesium plays an important role in root nodulation.
7. Sulphur is taken up by the plants in the form of SO_4.
8. Exchangeable magnesium is not readily available to plant.
9. Sulphur deficiency affects older leaves first.
10. Apatite is a source of Sulphur.

3.5 MICRO NUTRIENTS

Micronutrients are required in very small amounts, ppm (parts per million). However, they are as important as the macronutrients for the healthy growth of both plants and animals.

Major Functions of Micronutrients in Plants

1. Micronutrients are essential for the formation of chlorophyll (eg.iron,zinc,copper)
2. They are essential for stem elongation and normal root development (eg.zinc,boron)
3. They are required for enzymes activities in plants (eg. iron, manganese,copper, zinc, boron, molybdenum)
4. They are essential for nitrogen fixation (eg.cobalt, molybdenum)
5. They are required for photosynthesis (eg. cobalt, molybdenum)
6. Also play a role in protein synthesis (eg. manganese)
7. They play in the uptake and utilization of other essential nutrient elements

Forms and Sources of Micronutrients

Mircronutrients are mostly derived from soil parent material (primary and secondary minerals) and soil organic matter. Micronutrients are also added through fertilizer materials.

Micronutrients can occur in the soil solution either

(i) as simple cations or anions,
(ii) as complex inorganic ions or
(iii) as soluble organic complexes.

Important Factors Affecting the Plant Availability of Soil Micronutrient

1. Soil pH
2. Soil parent material (clay minerals)
3. Organic matter
4. Soil texture

5. Interrelationship with other elements deficiency:

Micronutrient Deficiency

Micronutrient deficiency is widespread in Indian soils.

Plants exhibit specific symptoms when they are suffering from a particular micronutrient deficiency. Some examples of plant symptoms are given in Table 4.

Table 4

Symptoms of Micronutrients Deficiency

	Micronutrients	Symptoms
1.	Zinc	Little leaf, rosetting, chlorotic, mottle in leaves
2.	Iron	Interveinal chlorosis; total bleaching followed by necrosis
3.	Manganese	Interveinal chlorosis; necrotic spots or streaks may appear
4.	Copper	Death of young leaves, chlorosis, failure of fruit set
5.	Boron	Death of growing points, leaf distortion
6.	Molybdenum	General paleness or mottled pale appearance (eg. whiptail in cauliflower)

INTEXT QUESTIONS 3.3

A. Fill in the blanks:

1. Micronutrients viz., _____ and _____ are required for nitrogen fixation.
2. Micronutrients are mostly derived from _____
3. Plants take up iron and boron mostly in the form of _____ and _____ respectively.
4. Whiptail in cauliflower is due to _____ deficiency.
5. _____ deficiency is most common in Indian soils

WHAT YOU HAVE LEARNT

Plants require about seventeen elements which are found essential for their growth.

Nitrogen, phosphorus, potassium, carbon, hydrogen and oxygen are required in relatively large amounts and therefore called as macro or major nutrients.

Calcium,magnesium and sulphur are called as secondary nutrients, as these nutrients are added through other fertilizers.

Other nutrients like Zinc, Iron,Manganese,Boron,Molybdenum, copper, cobalt and chlorine are required only in small amounts and hence called as micronutrients or trace elements.

Nitrogen is used largely in the synthesis of protein and chlorophyll.

Phosphorus is essential for flowering, fruiting and seed formation.

Potassium is necessary for enzyme activities, stomata function, water uptake and pest and disease resistance.

Calcium is essential root tips, transport of carbohydrates and protein.

Magnesium forms important constituent of chlorophyll molecule.

Sulphur helps in the synthesis of protein and enzymes.

Micronutients are generally activators of enzymes. They are essential for stem elongation,root development, and protein synthesis.,

Nutrients are derived from organic matter, minerals and chemical fertilizers.

TERMS YOU MUST KNOW (Glossary)

Essential nutrients	:	Nutrients which are required for the normal life cycle of the plant and whose function cannot be substituted by other chemical compounds.
Soil fertility	:	The nutrient supplying capacity of a soil for successful plant growth is referred as soil fertility.
Macro-nutrients	:	Nutrients that are used in relatively large amounts.
Micro-nutrients (trace elements)	:	Nutrients that are needed only in small amounts.
Mineral - N	:	Ammoniacal (NH^{+}_{4}) and nitrate (NO^{-}_{3}) nitrogen are mineral-N.
Mineralization	:	Microbial conversion of organic form of a nutrient into inorganic or plant available form
Nitrification	:	Microbial conversion of ammoniacal nitrogen into nitrate nitrogen.
Immobilization	:	Conversion of plant available (inorganic) form of nutrient in the soil to an unavailable (organic) form in microbial tissues is termed as immobilization.

Chlorosis	:	A deficiency symptom in plants. It is characterized by yellow colouring of the parts that are normally green such as leaves and stems, i.e., less chlorophyll is present.
Deficiency	:	Very low concentration of a particular nutrient in soil which affects plant growth

TERMINAL QUESTIONS

1. Define the essentiality of nutrients?
2. Classify the nutrient elements required by plants?
3. List the important functions of Phosphorus in plants?
4. Name the two micro organisms responsible for nitrification?
5. How nitrogen is lost from the soil?
6. Give a brief account of the role of micronutrients in plants?
7. Distinguish between
   a) Mineralization and Immobilization
   b) Nitrification and Denitrification
   c) Macronutrients and Micronutrients
8. Describe the forms and sources of secondary nutrients.

KEY OF INTEXT QUESTIONS

Intext Questions 3.1

a) 1. Soil fertility,
   2. Plant metabolism
   3. Ammonium (NH_4) and nitrate (NO_3)
   4. Low, low to medium, medium to high
   5. Fixed (non-exchangeable), slowly

b) 1. (c) 2. (c) 3. (a) 4. (c) 5. (d)

Intext Questions 3.2

1. False 2. True 3. False 4. True 5. False
6. False 7. True 8. False 9. False 10. False

Intext Questions 3.3

1. Cobalt and molybdenum
2. Soil parent material (mineral)
3. Ferrous (F^{2+}) & Ferric (F^{3+})
4. Molybdenum
5. Zinc

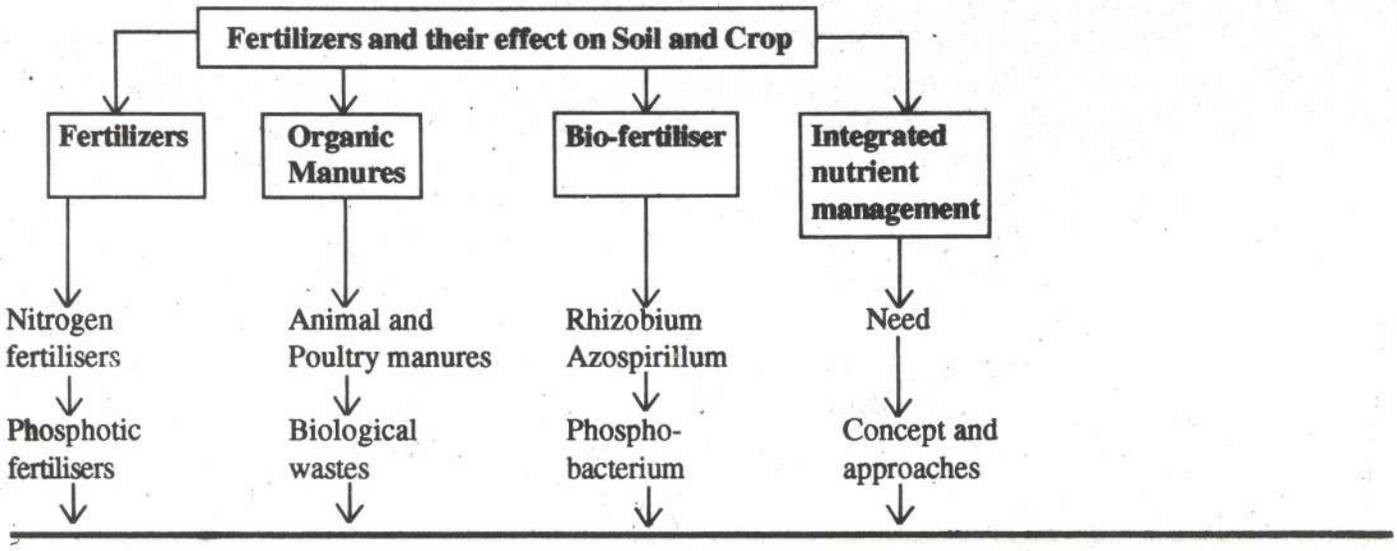
Module - 4

FERTILIZERS AND THEIR EFFECT ON SOIL AND CROP

INTRODUCTION

Indian soils are low in macro and micrountrient contents. This has become one of the principal limiting factors for achieving higher crop yields. Continuous farming also has diminished the inherent fertility of soil. Therefore to maintain soil health and fertility, fertilizers, manures and composts are addded to supply essential plant nutrients of crops. In this module, you will be learning about various fertilizers and their effect on crops.

KEY CONCEPT



Potassic fertilisers ↓ Sulphur fertilisers ↓ Calcium fertilisers ↓ Magnesium fertilisers ↓ Micronutrient fertilisers ↓ Mixed or Compound fertiliser

Green manures ↓ Green leaf manures

Modes of nutrient integration

OBJECTIVES

After studying this lesson, you will be abie to:

- define fertilizers, organic manures and biofertilizers;
- list out different types of fertilizer materials used in India;
- describe the reactions of fertilizers in soil;
- differentiate between fertilizers and organic manures.

4.1 FERTILIZERS

The term fertilizer refers to chemically synthesized (manufactured) plant nutrient compounds. They are usually applied to soil to supplement its natural fertility. Thus fertilizer becomes one of the most important as well as expensive input in agriculture.

Fertilizer may contain one or more of essential nutrients required for plant growth. Fertilizers which contain only one nutrient are know as single, simple or straight fertilizers (eg. urea). Fertilizers which contain two or more nutrients are classified as mixed or compound fertilizers (eg. diammonium phosphate).

Many materials like fertilizers manures and composts can be used to supply nutrients to plants. Mostly fertilizers are in inorganic form, while manures and composts are orgainc form. Serveral important differences between orgainc manures and inorganic fertilizers are given in Table 1.

Table 1

Important differences between inorganic fertilizers and organic manures.

Inorganic fertilizers	Organic manures
1. More or less pure minerals (Chemical substances)	Complex mixtures from animal and plant residues.
2. Relatively rich in plant nutrients	Bulky and poor in plant nutrients
3. Release nutrients more rapidly	Release nutrients slowly
4. When applied at high rates at planting time or too close to seeds or seedlings, salt damage is likely.	Salt damage is less likely
5. Highly water soluble; so more likely to be lost through leaching	Less water soluble; so less likely to be lost through leaching
6. Supply mainly only one or two nutrients chosen for the purpose	Supply more nutrients (N, P K, Ca, Mg, S) in addition to some micronutrients in small amounts.
7. Generally no effect on the physical condition of the soil	Improve the soil physical condition due to large amount of organic matter content

4.1. NITROGEN FERTILIZERS

The nitrogen (N) fertilizers may contain nitrate or ammonium or urea. Almost all the N fertilizers are extremely soluble in water and thus become readily available to plants. Chemically manufactured ammonia forms the basis for the production of most N fertilizers. Based on chemical form the N fertilizers are grouped as follows:

i) Ammoniacal fertilizers (NH_4 - N)

Examples	N content
a) Ammonium sulphate	(21.2%)
b) Ammonium chloride	(26%)
c) Anhydrous ammonia	(82%)

ii) Nitrate fertilizers (NO_3 - N)

a) Sodium Nitrate	(16%)

b) Potassium Nitrate (13%)

c) Calcium Nitrate (15.5%)

iii) Fertilizers containing ammonium and nitrate ions

a) Ammonium Nitrate (35%)

b) Calcium Ammonium Nitrate (25%)

C) Ammonium sulphate Nitrate (26%)

iv) Amide fertilizers $(NH_2)_2 CO$)

a) Urea (46.2%)

b) Urea phosphate (17%)

c) Urea sulphate (30 - 40%)

v) Nitrogen solution (Liquid fertilizers)

a) Anhydrous ammonia (82%)

b) Aqueous ammonia (varies)

vi) Slow release N fertilizers

a) Urea -formaldehyde (38%)

b) Oxamide (31.8%)

c) Metal ammonium phosphate (8%)

vii) Nitrification inhibitors

a) N-serve

b) Nitrapyrin

Liquid (solution) fertilizers are not commonly used in India. Only in foreign countries like USA,UK and European countries they are used. Among many different forms of N fertilizers, some important N fertilizers used in India are discussed below:

4.1.1.1 UREA ($CO(NH_2)_2$)

Urea is the most important N fertilizer used in India. A high N content and its ease of handling as prills have made urea the most popular form of N fertilizer. More than 70% of our Indian farmers use urea, since it is the cheapest source of N. Urea contains the highest N content (46%) than any soil fertilizer commonly used.

Manufacturing

Urea is manufactured by the reaction of ammonia and carbondioxide in a pressure reaction to form a melt containing urea, ammonium carbonate and water along with some ammonia. The primary source of raw materials for the manufacturing of urea are natural gas, air and water.

Properties of Urea

Urea is a white, fine crystalline water soluble compound and is hydroscopic (water absorbing substance). When applied to the soil urea undergoes rapid changes. The fate of urea in soil is illustrated in Figure 1.

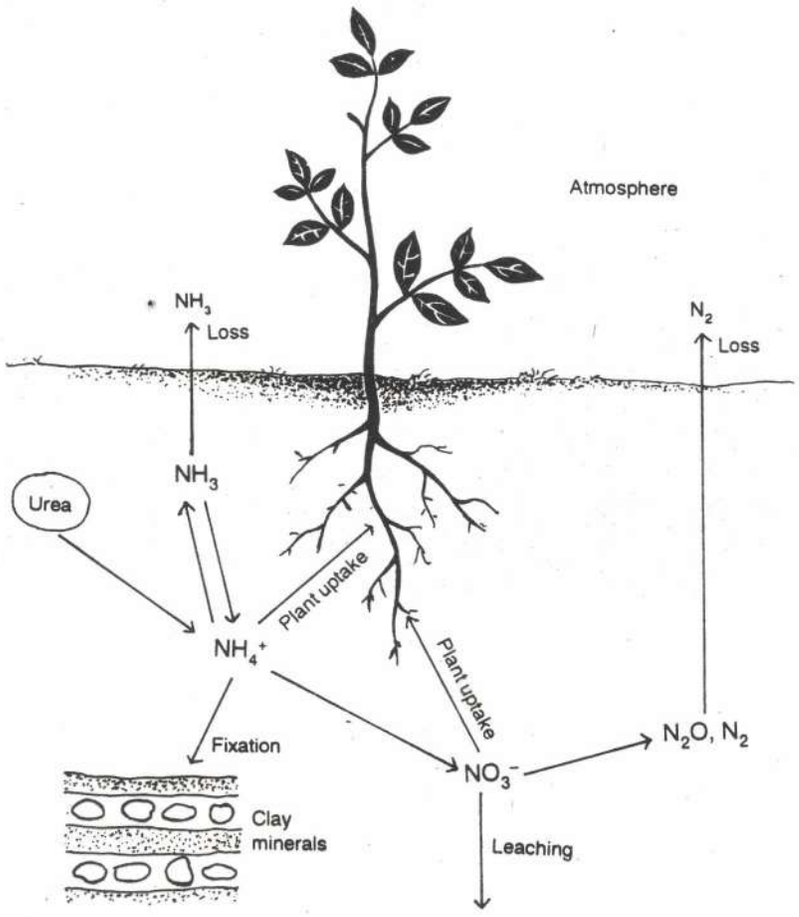


Figure 1. **Fate of Urea in soil**

In warm, moist soils, urea is rapidly hydrolysed to ammonia (NH_3) and carbondioxide (CO_2) by microorganisms. The NH_3 thus formed may be transformed into ammonium (NH^+_4) and/or lost through volatilization. The NH^+_4 is further subjected to microbial transformation and converted to nitrate (NO^-_3). Some NH^+_4 may be adsorbed or fixed by soil clays and organic matter which may not be available for crop uptake

Nitrate is very soluble in water and highly mobile. Therefore it is easily lost through leaching. The NO_3 may also be reduced to gaseous N (nitrous oxide and nitrogen) and lost through denitrification. Due to these losses of NO_3 ammoniacal form of N fertilizer is preferred over nitrate form.

4.1.1.2 SLOW RELEASE NITROGEN FERTILIZERS

We have seen from the preceding discussion that N added through urea or other chemical fertilizers is subject to may losses. As a result crop utilization of _N is very low (<40%). To minimise the loss of N and increase the effectiveness slow release N fertlizers have been developed. In these fertilizers,N is released slowly which provides N supply,continuously for longer period and is better matched with plant uptake rates.

Examples

i) UF - Urea formaldehyde (38%)

ii) CDU- Crotonylidene diurea (28% N)

iii) Oxamide (32%)

iv) Metal ammonium phosphates (7-10% N)

v) N- serve, USG-Urea Super Granule

4.1.1.3 COATED NITROGEN FERTILIZERS

To minimise the loss of N from urea, the prills or granules of urea are coated with the indigenously available cheap materials like neem cake,tar, gypsum and sulfur. Coating eliminates the risk of injury to plants from salt concentration. Coating also reduces the solubility of urea in water and its toxicity caused by a heavy rate of application.

Examples

i) Gypsum coate urea

ii) Neem blended urea

iii) Rock phosphate coated urea

iv) Lac coated urea

v) Sulphur coated urea

vi) Tar coated urea

Among the coated fertilizers, gypsum coated urea and sulphur coated area are advantageous because they also supply calcium and sulphur nutrients. The preparation of some of the coated fertilizers is discussed in the practical manual of this courses.

4.1.1.4 NITRIFICATION INHIBITORS

By inhibiting the process of nitrification, the loss of N can be minimised. Certain substances are toxic to the nitrifyig bacteria and inhibit nitrification. A nitrification inhibit (inhibitor) or should have the following important properties:

i) It should be nontoxic to plants and other organisms

ii) It should specifically inhibit the microorganism responsible for nitification

iii) It should not interfere with other soil processess

Examples

i) N-serve (2 Chloro 6 trichloromethy) 1 pyridine)

ii) Nitrapyrin

iii) AM (2- amino-4 Chloro-6 Methyl pyrimidine)

iv) DD (Dicyanadiamide)

v) TU (Thiourea)

4.1.2 PHOSPHORUS FERTILIZERS

Indian soils are, generally, low in phosphours (P) status and therefore it is necessary to apply P fertilizer for sustaining soil fertility. Phosphorus fertilizers are classified into three groups based on their solubility. They are as follows:

1. Water soluble phosphates

   eg: Superphosphate, diammonium phosphate

2. Citrate soluble phosphates

   eg: Dicalcium phosphate, Rock phosphates

3. Phosphates that are only soluble in strong mineral acids such as sulhuric, nitric or hydrochloric acid.

   eg: Tricalcium phosphates

Some important phosphorus fertilizers commonly used in India are described below:

4.1.3 Superphosphate

Superphosphate (single superphosphate) is widely used on agricultural and horticultural crops. It is manufactured from finely ground rockphosphate and concentrated sulphuric acid. Monocalcium phosphate ($Ca(H_2PO_4)_2$) is the most important component of superphosphate.

Properties of Superphosphate

Ordinary superphosphate is a gray-white granular fertilizer contains about 16-18% of phosphorus (P_2O_5) most of which is water soluble. In addition it also contains 21% calcium and 12% sulphur.

When superphosphate is added to soil, the soluble phosphates react with the soil constituents and become less soluble compounds depending upon the soil. In acid soils (pH less than 7),aluminimum and iron phosphates are formed.

Under certain conditions the phosphorous released from superphosphate may be adsorbed on the surfaces of soil minerals. In many soils, a large amount of phosphate reacts with the soil and become less soluble and less available to crops. The

conversion of available form into unavailable form is called phosphate fixation.

The response of crops to the superphosphate varies in different soils depending upon the nature of reaction of the superphosphate dissolved phosphate which exists in solution phase can be adsorbed by plant roots. In soils having high levels of organic matter, the dissolved P may be immobilized by microorganism.

4.1.2.2 Diammonium phosphate (DAP)

Diammonium phosphate is also a widely used P fertilizer. Commercial grade DAP contains 46 - 48% P_2O_5 and 16- 18% N. It is suitable for foliar spray. For pulses crop, foliar applications of DAP is recommended.

4.1.2.3 Ammonium polyphosphates

Ammonium polyphosphates are slow release P fertilizers. To reduce the P fixation and thus increase the efficiency, ammonium polyphosphate can be used for direct application or for bulk blending. The P content of this fertilizer ranges from 52-80% (P_2O_5).

4.1.2.4 Rock Phosphates

The raw materials for all phosphate fertilizers are the deposits of rock phosphates which are found in several areas of the world. In India rock phosphates (RP) mined in different parts of the country are being used as sources of phosphorus.

The total P content of RP varies from 11.5 to 18% (27 to 41% P_2O_5) and mostly they are insoluble. Rock phosphate is mostly suitable for acid soils. In neutral and alkaline soils rock phosphate can be used along with organic manures or bio-fertilizers. Various rock phosphates available in India and their phosphorus contents list in Table 2.

Table 2

Various rock phosphates available in India and Their P content

	Rock Phosphate	State where it is mined	Approximate P_2O_5 content (%)
1.	Mussoorie rock phosphate	UP	18 - 22
2.	Udaipur rock phosphate	Rajastan	22 - 24
3.	Purulia rock Phosphate	WB	20 - 25
4.	Lalitpur rock phosphate	UP	30
5.	Hirapur rock phosphate	MP	23
6.	Kasipatnam rock phosphate	AP	25 - 42

4.1.3 POTASSIUM FERTILIZERS

Potassium fertilizers are often referred to as potash fertilizers. Potassium is mined from abundant mineral deposits. Practically all of the potassium in combination with chloride, sulphate, nitrate. Commonly used potassium fertilizers in India are

i) Potassium Chloride and ii) Potassium sulphate.

4.1.3.1 Potassium Chloride (KC1)

In India potassium chloride is commercially marketed as 'muriate of potash'. Fertilizer grade muriate of potash contains about 60 -63% K2 O and varies in color from pink or red to white. Muriate of potash is manufactured from the minerals cornallite and sybrite through fractional distillation and crystallization.

When added to soil, muriate of potash dissolves in the soil water readily and is taken up plants. Some of the added potassium may be adsorbed on the soil colloidal complex or lost through leaching.

4.1.3.2 POTASSIUM SULPHATE ($K_2 SO_4$)

It is also known as 'sulphate of potash'. It is a fine yellowish salt which contains 50 - 53% K_2O and 17% sulphur. It has one important advantage over muriate of potash in that it can also supply adequate sulphur to the crop. Sulphate of potash is very effective on potatoes and tobacco, which are sensitive to large applications of chlorides.

INTEXT QUESTIONS 4.1

(A) Answer the following Questions:

1. What is a straight fertilizer? Give one example.
2. What is the percentage of N content in urea?
3. Ammonical form of N fertilizers are most preferred than nitrate forms, Why?
4. Give two examples each for a) slow release N fertiliz ers, b) Coated fertilizers.
5. What is the main source for manufacturing superphos phate?
6. List two important potassium fertilizers used in India.

(B) Fill up the blanks:

1. Fertilizers are mostly in_____form, where as manures and composts are_____form of plant nutrients.
2. _____ and _____ coated urea are advantageous because they also supply calcium and sulphur nutrients.
3. Substances which affect the nitrate production in soil are called as _____.

4. In India _____ and _____ also commonly used P fertilizers for agricultural and horticultural crops.
5. Rock phosphate is mostly suitable for _____.
6. _____ is recommended as foliar spray for pulse crop.
7. Sulphate of potash contains _____ % K_2O and _____% sulphur.
8. Potassium chloride is commonly known as _____.
9. _____ N fertilizers are not commonly used in India.
10. The losses of ammonia through _____ and nitrate through _____ and _____ reduce the efficiency of N fertilizers.

4.1.4 FERTILIZERS CONTAINING SECONDARY AND MICRONUTRIENTS

4.1.4.1 Sulphur Fertilizers

Sulphur (S) fertilizers contains S either in the form of sulphate or as elemental S. Sulphate is often present as a secondary constituent of fertilizers used mainly for nitrogen, phosphorus or potassium contents. Some important S containing fertilizers are listed in Table 3.

Table 3 : Important Sulphur containing fertilizers

	Name	Sulphur content (%)
1.	Ammonium sulphate	24.2%
2.	Gypsum	18.6%
3.	Sulphate of potash	17.6%
4.	Superphosphate	13.9%

All sulphates are relatively soluble, and when applied to the soil the S is in a form immediately available for plant uptake. However, sulphate can also be leached readily from the soil and adsorbed on soil clay.

4.1.4.2 Calcium fertilizers.

Calcium is not normally formulated as such, but it is present in many other fertilizer materials. Some of the fertilizers containing calcium are given in Table 4.

TABLE 4: Calcium containing fertilizers

	Name	Calcium content (%)
1.	Superphosphate	18 - 21
2.	Triple superphosphate	12 - 14
3.	Rock phosphate	33 - 36
4.	Gypsum	32.6
5.	Basic slag	32

When fertilizer is added, calcium is held as exchangeable ions by soil particles. Generally calcium is not subject to fixation. The calcium replaces sodium on the exchange complex, and the sulphate is leached through drainage water. This replacement helps to flocculate the soil and makes it more permeable to water.

4.1.4.3 Magnesium fertilizers

The most widely used magnesium fertilizers are listed in Table 5.

Table 5. Magnesium containing fertilizers

	Name	Managesium content (%)
1.	Epsom salt	9.8
2.	Magnesium sulphate	20
3.	Magnesia	55
4.	Serpentine	26

The reactions of magnesium containing fertilizers in soils are somewhat similar to calcium fertilizers. Magnesium may become fixed in the soil clay mineral and also be easily leached from soil.

4.1.5 Micronutrient fertilizers

Micronutrient deficiencies are widely spread in Indian soils (refer module 3). Micronutrient deficiencies in crops can be treated either by application of micronutrient containing fertilizers to the soil or by the application of micronutrient foliar sprays. Widely used fertilizers containing important micronutrient are given below:

- Boron (B) fertilizers
  Borax (11% B)
  Borates (14 - 21% B)
  (different grades)

- Copper (CU) fertilizers
  copper sulphate (25% Cu)
  copper chelates (9-13% Cu)

- Iron (Fe) fertilizers
  - Ferrous sulphate (19% Fe)
  - Ferrous amonium sulphate (14% Fe)
  - Pyrite (46.5% Fe)
- Manganese (Mn) fertilizers
  - Manganese sulphate (26 - 28% Mn)
  - Chelates (5 - 12% Mn)
- Zinc (Zn) fertilizers
  - Zinc sulphate (35% Zn)
  - Zinc chelates (9 - 14%Zn)
- Molybdenum (Mo) fertilizers
  - Ammonium molybdate (54% Mo)
  - Sodium molybdate (39% Mo)

Different micronutrient fertilizers have different reaction mechanisms which are very complicated. Micronutrients in fertilizer form simple cations or anions, as complex inorganic ions or as soluble organic complexes in the soil solution. For some micronutrients particularly copper, organic complexes may constitute a major proportion of their total solution concentration. The availability of micronutrients in soil is also influenced by interaction of various nutrients present. For example, high levels of any one of the micronutrient cations viz., iron, copper, Zinc., and manganese may induce deficiencies of the other. Similarly in some situations deficiency of zinc or iron can be induced by high soil phosphate levels.

Chelates

Chelates are complex organic compounds that can be used to correct micronutrient deficiencies. These chelates are quite effective, and therefore only small amounts are required to correct deficiency of the various micronutrients. Chelates can be applied directly to the soil or as foliar sprays.

Examples : EDTA, DTPA, EDDHA

4.1.6 MIXED OR COMPOUND FERTILIZERS

A mixed of compound fertilizer is a fertilizer containing any combination or mixture of fertilizer materials, Mixed or compound fertilizers contain two or more of the major plant nutrients. Most fertilizers can be mixed together without any adverse effects while some fertilizers react with one another. Balanced manuring with adequate provision for secondary and micronutrients can be achieved through mixed fertilizers.

It is required by legislation that all fertilizer bags should bear the guaranteed analysis of the contents of N,P and K. For example, the number 17:17:17 means that the fertilizer contains 17% N, 17% P_2O_5 and 17% K_2O. A guaranteed analysis of

16:17:0:20 means that the fertilizer contains 16% N, 17% P_2O_5, no K_2O, and 20% sulphur. Most compound fertilizers are granulated, prilled or pelleted. This makes them easier to handle, store and spread.

INTEXT QUESTIONS 4.2

(A) Match the following :

a)	Basic slag	1)	Micronutrient
b)	17:17:17	2)	Serpentine
c)	Sulphur	3)	Compound fertilizer
d)	Magnesium	4)	Calcium fertilizer
e)	EDTA	5)	Superphosphate

(B) Fill up the blanks:

1. Sulphur is present as _____ or as _____ in the fertilizers.
2. Gypsum can be used as _____ and _____ fertilizers.
3. Foliar spray is recommended for correcting _____ deficiency in plants.
4. _____ and _____ are commonly used to correct iron and zinc deficiencies
5. Deficiency of Zinc or iron can be resulted due to high soil_____.
6. Fertilizers which contain two or more of plant nutrients are called as_____.
7. A fertilizer guaranteed analysis of 20:17:0:15 indicates that the fertilizer contains 20%_____,17%_____0%, _____ and _____15%_____.
8. The complex organic compounds which are used to correct the micronutrient deficiency are called as _____.
9. _____ and _____ can be used to supply boron and molybdenum, nutrients to crop.
10. Superphosphate contains about _____ % calcium whereas gypsum contain _____% calcium.

4.2. ORGANIC MANURES

Organic manures are relatively bulky materials like animal or green manures, which are added to soil for increasing crop production. Organic manures are largely derived from plant and animal residues. They not only supply plant nutrients but also improve

the soil physical conditions by the addition of organic matter. Crop residues, municipal and domestic wastes, food processing wastes and byproducts from various industries are also used as organic manures.

4.2.1. Animal and Poultry Manures

Animal and poultry manures commonly known as farmyard manure, are valuable nutrient sources which have been used successfully to improve soil fertility for many centuries., Manure is faecal waste and urinary excretion of animal and poultry containing residues of litter or bedding materials. When the manure is decomposed due to microorganism the plant nutrients are released and will be available for plant uptake.

Nutrient content of various animal and poultry manures is given in table 6.

Table 6
Average nutrient content of animal and poultry manures (mixture of dung and urine)

Manure	Nutrient content % dry weight basis		
	N	P_2O_5	K_2O
1. Cattle	0.60	0.30	0.45
2. Goat and sheep	0.95	0.35	1.00
3. Pig	0.50	0.30	0.50
4. Horse	0.70	0.25	0.55
5. Poultry	1.8	1.20	0.80
6. Human waste (Night soil)	1.2	0.80	0.5

The nutrient content is highly variable due to type of animal, feed,methods of manure collection and storage etc., Apart from N,P and K, manures also contain appreciable amounts of other macro and micro nutrients.

4.2.2 Biological Waste

Apart from animal and poultry manures several waste products and by-products of various industries have also been used as organic manurers and their nutrient content are given in Table 7.

Table 7
Some common organic manures (other than animal manures) and their nutrient contents.

	Organic manure	Nutrient content, % dry weight basis		
		N	P_2O_5	K_2O
1.	Crop residues	0.3 - 2.5	0.2 - 1.5	0.6 - 2.5
2.	Urban and rural compost	0.4 - 1.0	0.3 - 0.6	0.6 - 1.0
3.	Wood chips, saw dust bark	0.2 - 1.9	0.4 - 2.5	0.5 - 3.5
4.	Coirpith (from coconut industry)	0.26	0.01	0.78
5.	Sewage sludge	2 -3.0	1.0 -5.0	0.2 -0.9
6.	Pressmud (sugar industry)	3.2	8.4	0.9
7.	Fish meal	5 - 10	1.0	—
8.	Blood and bone from slaughter house	6.1	6.9	

Non-edible oil cakes can also be used as organic manures. They contain about 3- 9% of N depending upon the nature of oil cake.

4.2.3. Green Manures and Green leaf Manures:

Certain plants particularly legumes can be grown and incorporated with the soil. Such practice is known as green manuring.

The green manure crops supply organic matter as well as nutrients. Since legumes fix atmospheric N, they are well suited for green manuring.

Crops suitable for green manuring:-

Dhaincha, Sunhemp, Pillipisara, Wild Indigo, Cluster beans, Cowpea.

Green leaves of some plants are collected and incorporated in the soil as manures. Such practice is called green leaf manuring. Crops suitable for green leaf manuring: Pungan, Neem, Glyricidia, Erukku (Calotropis)

INTEXT QUESTIONS 4.3

Choose the Correct Answer:

1. Organic manures are advantageous because they
   a) supply major plant nutrients
   b) add organic matter to soil
   c) release plant nutrients rapidly
   d) 'a' and 'b'

2. Among the animal and poultry manures, which contain more Nitrogen?
   a) cattle manure b) poultry manure
   c) pig manure d) sheep manure
3. Waste material obtained from coconut industry is
   a) compost b) pressmud
   c) coirpith d) bark
4. Sunnhemp is suitable for
   a) composting
   b) green manuring
   c) for extracting oil
   d) green leaf manuring
5. Which crop is most suitable for green leaf manuring
   a) Glyricidia b) Cowpea
   c) paddy d) Jute

4.3. BIOFERTILIZER

Biofertilizers are biological preparations containing some specific microbial inoculants which can fix nitrogen or mobilise phosphorus in soil. Cultures of these microorganism are prepared commercially and distributed to the farmers. Some algal species are also used as biofertilizers. For example the blue green algae (Anabaena azollae) is found to fix atmospheric N and hence used as biofertilizer for rice crop.

Important biofertilizers are listed in Table 8.

Table 8

Some important biofertilizers used in India

	Biofertilizer	Specific purpose
1.	Rhizobium (bacteria)	Nitrogen fixing for legumes
2.	Azospirillum (bacteria)	N fixing in cereal crops
3.	Blue green algae(algae)	N fixing for rice Crops
4.	Azotobacter (bacteria)	N fixing bacteria suitable for seed treatment
5.	Phosphobacterin (bacteria)	Phosphorus mobilising bacteria

INTEXT QUESTIONS 4.4

Match the following:

(a)	Anabaena	(i)	Suitable for seed treatment
(b)	Rhizobium	(ii)	N fixing in cereal crops
(c)	Phosphobacterin	(iii)	Algae which fix N in rice Soil
(d)	Azospirillum	(iv)	Phosphorus mobilization
(e)	Azotobacter	(v)	Bacteria Nitrogen fixing bacteria for legumes

4.4. INTEGRATED NUTRIENT MANAGEMENT (INM)

Chemical fertilizers play very important role in modern agriculture. However, continuous use of large amounts of these fertilizers leads to the deterioration of soil health and environmental pollution. To minimise these problems, integrated use of organic manures, crop residues and microbial inoculants along with chemical fertilisers is necessary.

4.4.1 Need for Integrated Nutrient Management

It is estimated that by the year 2000 AD, only two thirds of the total requirement of plant nutrients can be met through the use of chemical fertilizers. The remaining one third should be obtained from the organic manures and the recycling of biological waste materials.

In additions, the escalating prices of fertilisers and their unavailability at appropriate time warrants the approach of integrated nutrient management.

4.4.2 The various concepts and approaches that are involved in INM are:

- Incorporation of organics, compost, night soil, farm yard manure and green manure
- Enrichment of these organics with inorganic nutrients
- Combined use of organics with microbial inoculants or inorganic fertilizers

Integrated approach aims at optimum usage (dose) of both organics and inorganics in a correct proportion so that full potential of both the sources are obtained.

4.4.3 Different modes of Nutrient Integration

1. Use of organics with Chemical fertlizers

The combined use of chemical fertilisers with the following organics have been found very effective in increasing the crop yield, besides improving the physical properties of soils:

(a) Farm yard manure (12.5 t/ha)

(b) Compost (6 to 10 t/ha)

(c) sewage Sludge (20 t/ha

(d) Press mud (10 t/ha)

(e) green manure (6.25 t/ha)

(f) Crop residues (10 t/ha)

2. Inclusion of legumes in the crop rotation

   (eg.) Cowpea, Blackgram, Greengram etc.

3. Use of appropriate agronomic practices

   (eg.) Split application of nitrogen at important stages of crop growth

4. Soils and Crops

   Fertiliser management should be specific to certain soils and crops

5. Balanced fertiliser

6. INM for Micronutrient

7. INM specific to Rainfed

INTEXT QUESTIONS 4.5

Fill up the blanks

1. Integrated Nutrient Management implies the integrated use of _____, _____ and _____ along with chemical fertiliser

2. By the year 2000 AD, it is estimated that _____ of the total requirement of plant nutrients should be met through the organic manures.

3. Microbial inoculants are used in Integrated Nutrient Management mainly to promote_____ and _____

4. Both organics and inorganics should be used at _____ and in a _____ to get full benefit.

5. It is normally recommeded that green manure at a rate of _____ or compost at a rate of _____ should be used in combination with recommeded levels of NPK fertilisers

WHAT YOU HAVE LEARNT

Fertilisers and manures are needed to maintain the soil fertility. Fertilizers are mostly in inorganic form, while manures are in organic form.

Nitrogen fertilizers are available in various forms. Ammoniacal fertlizers are preferred over nitrate forms. Urea as nitrogenous fertlizers is most widely used in India. To increase the effectiveness, slow release N fertilizers, nitrfication inhibitors and coated fertilizers are used.

Among the phosphorus fertilizers, superphosphates and diammonium phosphates are widely used. Rock phosphate can be used especially in acid soils.

In India muriate of potash (kcl) and sulphate of a potash (K_2SO_4) are commonly used as K fertilizers.

Nutrients like Ca, Mg, S often present as a secondary constituent in N, P & K fertilizers. For example both Ca, and S are present in fertilizers.

Micro nutrient deficiency can be corrected through micronutrient fertilizers.

Mixed or compound fertilizers are available to supply one or more plant nutrient.

Organic manures supply plant nutrients, add organic matter and improve the physical properties of soil.

Animal, poultry manures, sewage sludge, coirpith, crop residues, pressmud, woodchips and compost are used as organic manures.

Microbial inoculants which can fix N or mobilise P in soil are used as biofertilizers.

The integrated use of organic, chemical and microbial fertilizers will lead to the build up of soil fertility, increase in crop propductivity, with nutrient balances besides minimising the pollution hazards as well as the fertilizers cost.

TERMS YOU MUST KNOW

Fertilizers	:	Chemically manufactured plant nutrient compounds.
Single or straight fertilizer	:	Fertilizers which contains only one plant nutrient.
Mixed or compound Fertilizer	:	Fertilizer which contains two or more plant nutrient.
Slow release N fertilizer	:	Fertilizers which release N slowly but continuously for a long period.
Coated fertilizer	:	Fertilizers (urea) coated with various materials like gypsum, sulphur, tar, rock phosphate etc., are known as coated fertilizers, to reduce the loss.
N-inhibitors	:	Substances which inhibit the process of nitrification (nitrate formation).
Chelates	:	Organic compounds containing micronutrients.
Organic manures	:	Plant and animal wastes used as source of plant nutrients and organic matter.
Green manuring	:	Practice of growing a plant purposely and incorporating it in the soil for supplying plant nutrients.
Green leaf manuring	:	Practice of green leaves of some plants incorporating in the soil as manures.

Biofertilizers : Biological preparations containing microbial inoculants which can fix N or mobilise P.

TERMINAL QUESTIONS

1. How will you differentiate between fertilizers and manures?
2. List different forms of N fertilizers and give two examples in each group.
3. What happens when urea is applied to soil?
4. What is coated fertilizer? Give few examples.
5. Write of short notes on the following fertilizers:
   (a) Superphosphate, (b) Chelates,
   (c) Muriate of potash (d) Rock phosphate.
6. Name few fertilizers which contain major nutrients and secondary nutrients.
7. Why mixed or compound fertilizers are advantageous over straight fertilizers?
8. What are the organic manures used in your region?
9. Differentiate between green manures and green leaf manures. Give examples.
10. Define biotertilizers. List some important biofertilizers used in India.
11. What is integrated nutrient management. Describe different modes of nutrient integration.

KEY TO INTEXT QUESTIONS

INTEXT QUESTIONS 4.1

(A) 1. Fertilizer which contain only one plant nutrient is known as straight fertilizer. Example: urea

2. 46.2%

3. Nitrates are very soluble in water. So they are leached and lost from the soil. Further, nitrates are also subject to denitrification losses. These losses reduce the efficiency of nitrate fertilizers. Such losses are minimum with ammoniacal form of N fertilizers.

4. Slow release N fertilizer

   (eg) Urea formaldehyde

   Crotonylidene diurea

   Coated fertilizers

   (eg) gypsum coated urea

   Sulphur coated urea

5. Rock phosphate and sulphuric acid
6. i) Muriate of potash (Kcl)
   ii) Sulphate of potash (K_2SO_4)

(B) 1. Inorganic, organic
2. Gypsum, sulphur
3. Nitrification inhibitors
4. Superphosphate, diammonium phosphate
5. Acid soils
6. Diammonium phosphate
7. 50 - 53%, 17%
8. Muriate of potash
9. Liquid
10. Volatilization, leaching, denitrification.

INTEXT QUESTIONS 4.2

A. (a) iv (b) iii (c) v (d) ii (e) i

B. 1. Sulphate, elemental S
2. Calcium and sulphur
3. Micronutrient
4. Ferrous sulphate, Zinc sulphate
5. Phosphate
6. Mixed or compound fertilizers
7. N,17%, No+K20, Sulphur
8. Chelates
9. Borax, Ammonium molybdate
10. 18 - 21, 32.6

INTEXT QUESTIONS 4.3

1. (d) 2. (b) 3. (c) 4. (b) 5. (a)

INTEXT QUESTIONS 4.4

(a) iii (b) v (c) iv (d) ii (e) i

INTEXT QUESTIONS 4.5

1. Organic Manures, Crop residues, Microbial inoculants

2. One third
3. Nitrogen fixation, Phosphorous mobilisation
4. Optimum dose, correct proportion
5. 6.25 t/ha, 12.5 t/ha, 10 t/ha

Suggested Readings

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