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SOIL AND PLANT NUTRIENTS

31.1 INTRODUCTION

Can you think of a substance that has many meanings for humanity? There has been, and is, one known as the soil. The concept of soil as a medium of plant growth was born in ancient times and remains as one of the most important concept of soil today. Soils are complex systems which are highly variable from region to region, but they universally consist of various proportions of three phases solid, liquid and gas. In addition soils generally contain diverse communities of inter-dependent plants, animals and micro-organisms.

31.2 OBJECTIVES

After reading this lesson, you will be able to :

- explain the term soil
- describe formation of soil
- state the characteristics of different types of soil
- enumerate the soil texture
- describe soil reaction
- distinguish between micro and macro-nutrients required by the plant; and
- explain the method of uptake of plant nutrients.

31.3 SOIL COMPOSITION

One gram of soil contains about 10^8 organisms (algae, fungi, bacteria, mites, insects, nematodes to name only a few). Some of these organisms are beneficial and some are

detrimental. Interaction between soil organisms are very complex. The underground parts of plants, consisting mostly of roots, are constantly exposed to organisms in soil as well as to variable physical environment which includes moisture, temperature, pH and a wide range of chemical factors.

If you slice straight down most of the soils, you will find a typical profile (a vertical section of the soil) consisting of a relatively thin organic layer at the top that contains mostly dead and decaying organic matter (the A horizon), below which is a layer containing a mixture of decayed organic matter and small pieces of minerals (the B horizon). The final layer in a soil profile, just above the bed rock, consists of small pieces of the mineral components but little or no organic matter (the C horizon) (Fig. 31.1).

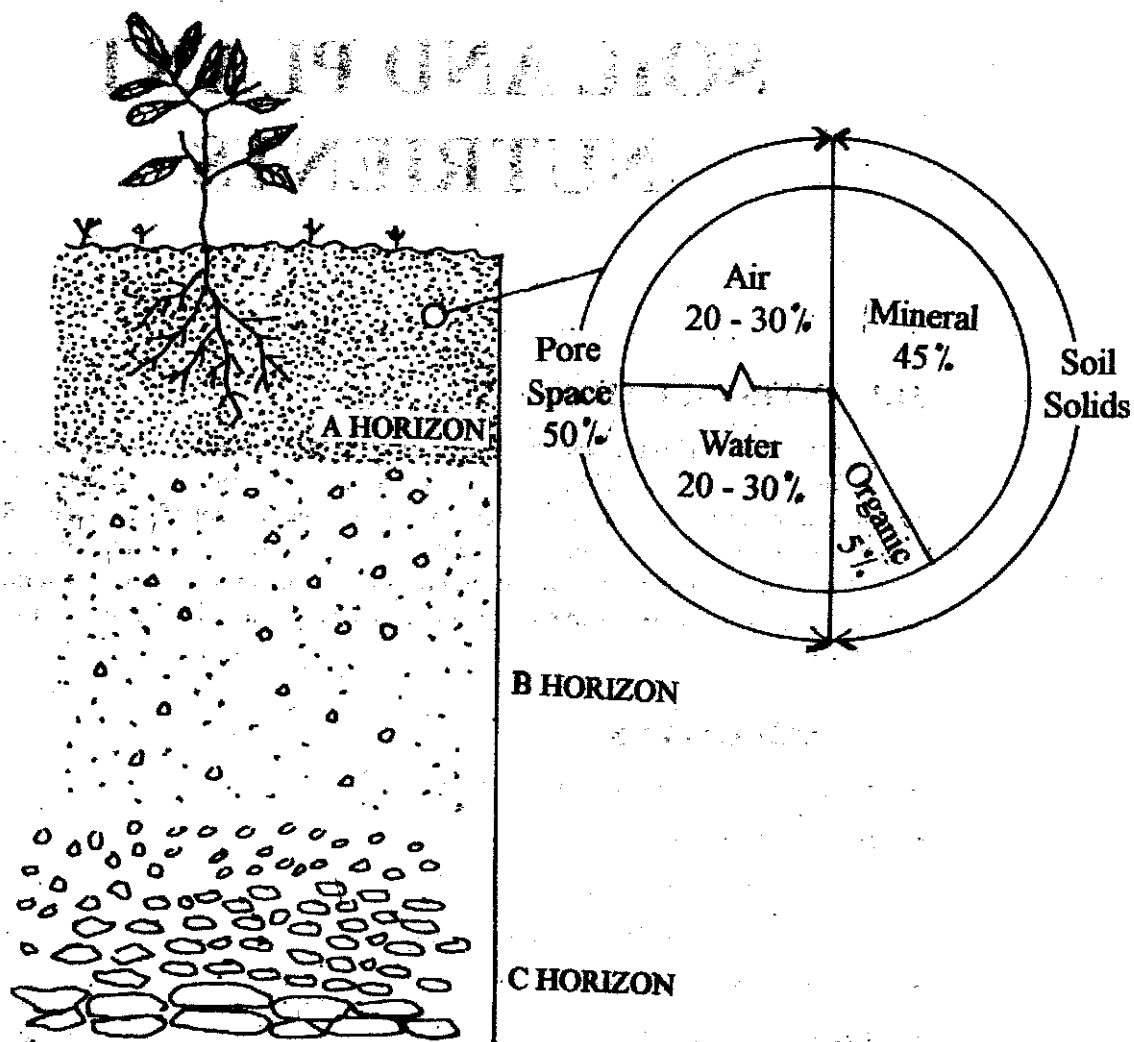


Fig. 31.1 : Composition of Soil

Water is present in soil in a thin layer on the surface of the soil particles and also as free water in the spaces between soil particles. Because water molecules have a tendency to cling together, the water in the tiny spaces between soil particles is drawn downward by gravity, but also held in the pore space by the affinity of water molecules. Soil consists of

pore spaces between soil particles. When soil moisture is normal, half of the pore spaces are filled with air and the other half are filled with water.

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

31.4 FORMATION OF SOIL

The soils were created slowly over millions of years. On the rocky surfaces of the land masses, erosion by wind, rain, glacial ice, freezing and heating broke up the minerals of the larger rocks into small pieces. Plants contributed to the break down of the rocks. The mineral particles became mixed up with decaying organic materials from microorganisms, animals and plants that had once been alive. Thus a soil is influenced from the beginning by the inorganic underlying bed rock and the rocky materials carried by glaciers and water as well as by the organic matter contributed by the organisms living on the surface.

31.5 TYPES OF SOIL

The major soil groups of India are :

31.5.1 Alluvial Soils

Alluvial soils cover the largest area in India by dominating in Northern, Western and Eastern parts of India. These are the most important soils from the agricultural point of view. These soils are formed from mountaineous rocky materials and carried by rivers, water, ice and wind by the influence of gravity. Alluvial soils have a wide range of characteristics sandy to clay, acid to alkaline, normal to saline, shallow to very deep and sodic or calcareous rich in sodium or calcium salt. The colour of surface soil varies from pale grey to yellowish brown. The dominant clay mineral in these soils is illite.

31.5.2 Black Soils

These soils are locally known as regurs or black cotton soil, as cotton is the main crop growing on it. Black soils are dominant in peninsular region of the country. Black soils are characterized by dark grey to black colour, high clay content, neutral to slightly alkaline in soil reaction (pH). These soils have high swelling and shrinkage properties. On the surface of the soil deep cracks occur during summer. Black soils are dominant in smectite type of clay minerals.

31.5.3 Red Soils

Red soils, generally red or reddish brown, are derived from the decomposed rock materials washed down to lower level by rain. These soils are formed under well drained condition. Red soils have lighter texture, loose structure, absence of free lime, and low in soluble salt content. These soils are slightly acidic to slightly alkaline in soil reaction. The dominant clay mineral is kaolinite.

31.5.4 Laterite Soils

The formation of laterite soil takes place by leaching of silica due to rains and the upper surface becomes rich in oxides of iron and aluminium. The colour of the soil is purple to brick red. These soils are very poor in calcium and magnesium and generally well drained and porous. The pH is generally low. The dominant clay mineral in laterite soil is also kaolinite.

INTEXT QUESTIONS 31.1

1. What is soil ?

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2. State different horizons of soil.

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3. How did formation of soil take place ?

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4. What are alluvial soils ?

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31.6 SOIL TEXTURE

The relative proportions of the various soil separates (sand, silt and clay) in a soil is known as soil texture.

The size and relative proportions of the soil separates and determines the soil type. Soil particles vary in size and range from sand (0.02-2mm) to silt (0.002 – 0.02 mm) to the smallest called clay (< 0.002 mm). Where sand predominates, the soil contains relatively larger spaces between the particles, allowing rapid drainage after a rain. In clay soils the smallest particles predominates, the space between particles are tiny; and the drainage may be slow. Some of the best agricultural soils are loams, in which a balance exists between sand, silt and clay. Therefore, three broad groups of soil textural classes are recognized – sands, loams and clays. Within each group specific textural class names have been identified (Table 31.1)

Table 31.1 Soil texture and basic textural class names

Broad names	Texture	Basic soil textural classes
Sandy soils (Sand \geq 70%)	Coarse	Sands Loamy sands
	Loamy soils	Moderately coarse
Medium		Loam Silty loam Silt
Moderately fine		Sandy clay loam Silty clay loam Clay loam
Clayey soils (Clay \geq 35%)	Fine	Sandy clay Silty clay Clay

31.7 SOIL REACTION

The most outstanding characteristics of the soil is its reaction i.e. whether it is acidic, alkaline or neutral. Soil reaction controls most of the chemical and biological properties of soils.

The soil reaction is soil pH which represents the concentration of hydrogen ions [H⁺] and hydroxyl ions [OH⁻] in the soil solution.

The adsorption and distribution of various nutrient elements by fine solids depends on soil pH. The solubilities of main soil constituents are influenced by soil reaction. Since various minerals of soils dissolve at different pH values, microorganisms and higher plants respond markedly to soil reaction because it tends to control much of their chemical environment.

Soil pH can be determined in the laboratory by pH meter. Technically the pH is the negative logarithm of hydrogen ion [H⁺] concentration in solution.

$$\text{pH} = -\log [\text{H}^+]$$

Thus each unit change in the pH represents a ten fold change in the activity of the H⁺ and OH⁻ ions. pH values in the range of 0 to 7 indicate soil acidity, where as in the range of 7 to 14 indicate soil alkalinity and 7 being the neutral point. For example, pearl millet, tea and wheat need alkaline, acidic and neutral soil reaction respectively for the better plant growth.

31.8 SOIL NUTRIENTS

Plants require food for growth and development like animals and human beings do. It is composed of certain chemical elements known as nutrients.

Soil nutrient can be defined as "a chemical element essential for the proper growth and development of plant."

There are sixteen essential nutrients (C, H, O, N, P, K, Ca, Mg, S, B, Zn, Cu, Mn, Fe, Mo and Cl) which are required for plant nutrition. These nutrients are absorbed by plant roots from the soil in the solution form. It is impossible for the plant to complete the vegetative and reproductive stage of its life cycle in the absence of these nutrients. The deficiency is specific to the nutrient element and can be prevented or corrected only by supplying particular nutrient to the plants.

Among the nutrient elements carbon and oxygen are obtained directly from air and photosynthesis (process of manufacturing food). Hydrogen comes directly or indirectly from soil water. The remaining nutrients are obtained by plants from soil.

31.9 MICRO AND MACRO NUTRIENTS

Micronutrients are required in very small amounts by plants for their proper growth. Out of sixteen nutrient elements, seven namely B, Zn, Cu, Mn, Fe, Mo and Cl are micronutrients. The factors that determine the amounts of micronutrients available to plants are closely related to soil condition and plant species. For example, a change in soil pH can change a deficient situation for plants into a toxic situation. Although micro-nutrients

are necessary elements, they can cause toxicity symptoms in the plants if present in excessive amounts.

Table 31.2 Essential plant nutrients

Nutrients	Classification	Source
C, H, O N, P, K Ca, Mg, S	Macro-nutrient	Water and air, Soil, organic manures and chemical fertilizer
B, Zn, Cu Mn, Fe, Mo Cl	Micro-nutrient	Soil, organic manures and chemical fertilizer

Nine of essential nutrients (C, H, O, N, P, K, Ca, Mg, S) are used in relatively large amounts and are the macronutrients, usually over 500 parts per million (ppm) in the plant. C, H and O are supplied by carbon dioxide and water while other macronutrients are dissolved in the soil water in various chemical forms and absorbed primarily through roots. Nitrogen, phosphorus and potassium are required in largest quantity. The chemical forms and relative amounts of these elements vary with time to application. These are commonly added to the soil through chemical fertilizers.

Table 31.3 Difference between macronutrients and micro nutrients

Macronutrients	Micronutrients
1. They are required in large amounts	They are required in very small amounts
2. They are nine in number (C, H, O, N, P, K, Ca, Mg and S)	They are seven in number (B, Zn, Cu, Mn, Fe, Mo and Cl)
3. Their concentration in the plant is usually over 500 ppm.	Their concentration in the plant is less than 100 ppm.
4. They are involved in the development and growth of the plant	They are mainly involved in plant enzyme systems.

INTEXT QUESTIONS 31.2

1. Explain soil texture.

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2. Give the basic soil textural classes.

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3. Why is soil reaction important ?

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31.10 UPTAKE OF NUTRIENTS FROM SOIL

The plant nutrients are based in the solid phase; and their usual pathway to plant system is through the surrounding liquid phase to soil solution, and then to the plant root and the plant cells. Plants roots take up plant-food elements from soil in ionic forms. The positively charged ions are called 'cation' which include potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}), iron (Fe^{++}), zinc (Zn^{++}) and so on. The negatively charged ions are called 'anions' and the important plant nutrients taken in this form include nitrogen, phosphorus, sulphur, chlorine etc. which are absorbed as NO_3^- , $H_2PO_4^-$, SO_4^- and Cl^- ions, respectively.

Nutrient absorption involves the phenomenon of ion exchange. The root surface, carries a negative charge and exhibits cation-exchange property. The most efficient absorption of plant nutrients takes place on the younger tissues of the roots which are capable of growth and elongation.

Air is the primary source of nitrogen for plant nutrition and only leguminous crops (pulses) can directly use this free nitrogen with the help of symbiotic **Rhizobium**, about which we will learn in Lesson 34.

31.11 WHAT YOU HAVE LEARNT

- The various phases that constitute soils, viz. solid, liquid and gas.
- The major horizons which constitute physical environment of the soil.
- The underground parts of plants, consisting mostly roots are constantly exposed to indefinitely large number of organisms in the soil as well as to variable physical environment, which includes moisture, temperature, pH and a wide range of chemical factors.
- A soil is influenced from the beginning by the inorganic underlying bedrock and rocky material and water as well as organic matter.
- Water is present in soils in the form of a thin layer on the surface of the soil particles and also as free water in spaces between soil particles.
- Silt loam soils are excellent for agricultural uses.
- The essential elements are necessary for the growth and development of plants.
- The size and relative proportion of the mineral particles determine the soil type.
- The major soil groups of India are alluvial soils, black soils, red soils and laterite soils.
- Soil reaction controls the chemical and biological properties of the soil.
- Plant roots take up food elements in ionic form.

TERMINAL EXERCISE

1. What is the composition of soil ?
2. In what way is water present in soil ?

3. What are the three phases of soil ?
4. What do you know about red soils ?
5. Describe laterite soils.
6. Write in detail about black soils.
7. Give the importance of relative proportions of various soil mineral particles.
8. Define soil reaction.
9. What are soil nutrients ?
10. Why are micronutrients important ?
11. Tick mark (✓) the correct answer.
 - i. Which one of the following are macronutrients ?
 - a) Mn
 - b) Fe
 - c) K
 - d) Cl
 - ii. Which one of the following are micronutrients ?
 - a) C
 - b) N
 - c) P
 - d) Mo
12. Fill in the blanks.
 - i) 1 g of soil contains about _____ organisms.
 - ii) The top layer of dead and decaying organic matter is _____.
 - iii) A layer containing mixture of decayed organic matter is _____.
 - iv) Soil particles range from 0.02 to 2.0 mm in _____.
 - v) Soils characterized by swelling and shrinkage are termed as _____.
13. Indicate whether the following statements are true (T) or False (F)
 - i) Water is absent in soil. T/F
 - ii) Cotton is the main crop of red soil. T/F
 - iii) Plants take nutrients in ionic form. T/F
 - iv) Air is primary source of nitrogen. T/F
 - v) Zinc influences the formation of growth hormones. T/F
14. What is the difference between macronutrients and micronutrients ?
15. List the macro- and micronutrients.

CHECK YOUR ANSWERS**KEY TO INTEXT QUESTIONS 31.1**

1. Soil is a natural body composed of mineral and organic materials and living forms in which plants grow.
2. A, B and C horizons.
3. Refer to 1.4
4. Refer to 1.5.1

KEY TO INTEXT QUESTIONS 31.2

1. Refer to 1.6
2. Refer to 1.6
3. Refer to 1.7

TERMINAL EXERCISE

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|------------------------|--|
| 1. Refer Section 1.3 | 11. i) c
ii) d |
| 2. Refer Section 1.3 | |
| 3. Refer Section 1.1 | 12. i) 10^8
ii) A horizon
iii) B horizon
iv) Sand
v) Black soils |
| 4. Refer Section 1.5.3 | |
| 5. Refer Section 1.5.4 | |
| 6. Refer Section 1.5.2 | 13. i) False
ii) False
iii) True
iv) True
v) True |
| 7. Refer Section 1.6 | |
| 8. Refer Section 1.7 | |
| 9. Refer Section 1.8 | 14. Refer Section 1.9 |
| 10. Refer Section 1.9 | 15. Refer Section 1.11 |