Module -I: SOIL-WATER-PLANT ATMOSPHERE RELATIONSHIP

1. SOIL WATER

i) INTRODUCTION

When you are walking on a ploughed field, some dust particles will adhere your feet. If you then take some dry soil in your hand, you will find the soil particles visible in the naked eye. It will give you an impression that soil is composed of only solid particles. Now keep the dry soil in a pot and pour small quantity of water on the surface of the soil. You will see that water enters the soil. Where this water goes? It enters the spaces in the soil. As the water enters the soil spaces, air is displaced and the surface soil 'wets up'. Continued application will result in further downward movement of water and simultaneous air replacement. At last the water will appear on the soil surface when all the spaces in the soil are completely filled with water. Now keep the pot containing moist soil under the sun. The soil will release water to the atmosphere and the soil spaces not occupied by water are then filled with air. Besides water and air, soil also contains living organisms like earthworm, bacteria etc.

In this lesson we are going to study the soil, its different phases and physical properties, soil water and its availability for plant growth.

ii) KEY CONCEPTS

Retention, movement and availability of soil water to plants.

iii) OBJECTIVES

After studying this lesson you will be able to :

- *state about the different components of soil*
- *explain the functions of these components*
- *understand about the sources of essential nutrient element needed by the plant*
- *know that the soil acts as a storehouse of plant nutrients*
- *recognise the importance of soil as a water reservoir*
- *understand the soil and water relationship*
- *recognise the portion of soil water available to plant.*

1. 1. COMPONENTS OF SOIL

Examination of soil reveals that the soil has solid particles and the spaces in between these particles are occupied by air, water or living organisms. So the soil has four component phases viz., solid phase, liquid phase, gaseous phase and living phase.

(i) SOLID PHASE

You have seen that farmers apply cowdung, decomposed green matter etc. in the fields and mix them thoroughly with soil. These materials are known as organic matter. These organic matters are in intimate contact with soil particles. It is an important source of some mineral elements needed by the plant. It also tends to increase the amounts of water a soil can hold and the proportion of this water that is available for plant growth, Organic matter is the main source of energy for soil microorganisms. Soil solid phase contains mineral materials and organic matter. It exists in the form of particles of various sizes which provide the soil matrix. The volume of soil not occupied by soil particles is known as pore space. The soil pores are of two types viz., macro(bigger) and micro(smaller) pores. Through macro pores water and air can move freely whereas through micro pores, the movement of water and air is very slow. The solid phase also helps in the anchorage of plants.

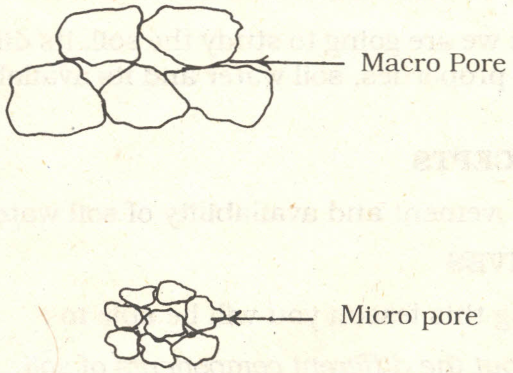

Fig. 1 Pore space of Soil Macro pore

(ii) LIQUID PHASE

If some sugar is added to a glass of water and stirred for sometimes, the sugar is dissolved and the water containing sugar is known as solution. Similarly the liquid phase of soil is mainly constituted by water which contains dissolved salts and nutrients. This is soil solution. When we apply fertilizers like urea or ammonium sulphate to the soil, these solid fertilizers are dissolved in soil water and form a part of the soil solution, which is an important medium for supplying nutrients to plants. Water of the liquid phase is held within the soil pores with varying degrees of tenacity depending on the amount of water present. Liquid phase has two important functions : (a) it supplies water to the plant and (b) it helps in the availability of soluble nutrients needed for the plant.

(iii) GASEOUS PHASE

You have learnt that soil pores not filled with water are occupied by air. Soil air is utilised by plant roots for their respiration and by soil microorganisms for their activities. Because of respiration by plant roots and soil microorganisms which consume oxygen and liberate carbon dioxide, soil is poorer in oxygen and richer in carbon dioxide content than atmospheric air. Soil air generally has a higher moisture content than the atmosphere, the

	Atmospheric air (per cent)	Soil air (per cent)
Oxygen	20.97	20.65
Carbon dioxide	0.03	0.25
Nitrogen	79.00	79.20

relative humidity approaching 100 per cent when soil moisture is optimum. The soil pores are shared between soil water and soil air. As the amount of one increase, that of the other decreases.

iv) LIVING PHASE

You have seen that termites attack the wood and disintegrates the hard wood into a soft mass. Similarly soil microorganisms disintegrate solid organic matter of soil and transforms them into soluble and available form. The mineral soil harbours a varied population of living organisms. The whole range in size from the large rodents, worms and insects to the tiniest bacteria commonly occurs in normal soils. Activities of soil organisms vary from the largely physical disintegration of plant residues by insects and earth worms to the eventual complete decomposition of these residues by smaller organisms such as bacteria, fungi and actinomycetes. Accompanying these decaying processes is the release of several nutrient elements from organic combination. The essential elements for plant growth is converted into available forms by these organisms. Many conditions of the soil affect the growth and activities of these soil microorganisms. The most important conditions are the supplies of oxygen and moisture in soil.

1.1 INTEXT QUESTIONS

1. List the component phases of soil
2. Which of the following is richer in carbon dioxide content?
   (a) Atmospheric air (b) Soil air
3. Make correct pairs from the two columns

a. Organic matter	A. Liquid phase of soil
b. Dissolved nutrients	B. Living phase of soil
c. Carbon dioxide	C. Gaseous phase of soil
d. Bacteria	D. Solid phase of soil

1.2 STOREHOUSE OF NUTRIENTS

All living beings take food for their maintenance. We eat solid food and drink liquid food. Plant can not take solid food, it absorbs nutrient from soil solution. You have seen the farmers distributing urea fertilizer on his field. Urea contains nitrogen which is needed by the plant. Similarly super-phosphate supplies phosphorus, and muriate of potash supplies potassium to the plant. These elements are essential for plant. Plant needs such 16 essential elements for their growth and development. These are following :

Essential Elements of Plants

S.No	Essential Elements of Plants		Sources
1.	Carbon		Carbon, di-oxide and water
2.	Hydrogen		
3.	Oxygen		
4.	Nitrogen	Macro Nutrients	Soil
5.	Phosphorous		
6.	Potassium		
7.	Calcium		
8.	Magnesium		
9.	Sulphur		
10.	Iron	Micro Nutrients or Trace Elements	
11.	Manganese		
12.	Zinc		
13.	Copper		
14.	Boron		
15.	Molybdenum		
16.	Chlorine		

1.3 SOIL PHYSICAL PROPERTIES

When we add water to a sandy soil, it quickly absorbs water whereas clay soil absorbs water very slowly. Why these two soils behave differently? The study of the physical properties of soil will give you the answer. These properties help to determine, not only the nutrient - supplying ability of soil solids but also the supply of water and air, so important to plant life. Two important physical properties of soil are soil texture and soil structure.

i) SOIL TEXTURE

Soil texture refers to the relative proportion of the various size groups of mineral particles in a given soil. The size groups are sand, silt and clay having the following diameter limits.

Soil group	Diameter limits (mm)
Sand	2.00 - 0.02
Silt	0.02 - 0.002
Clay	below 0.002

Soil with more than 70 per cent sand particles is called sandy soil, with more than 40 per cent clay particles as clay soil. If all three soil fractions are in sizeable proportion, the soil is called as loamy soil.

Because of the large size of sand particles, the spaces in between the particles are larger, which facilitate free movement of air and water. So the sandy soils facilitate good drainage but have very low water holding capacity. Sandy soils are loose, friable and easy to handle in tillage operations. Hence they are known as light soils.

Small size of clay particles form micropores and so they have poor drainage and aeration, but have a high capacity to absorb and retain nutrients and moisture. Clay soils have high water holding capacity. They are very difficult to handle in tillage operations and hence they are called heavy soils.

Loamy soils having sand, silt and clay fractions in sizeable proportion, exhibit properties intermediate between sandy and clay soils. They are considered best for agricultural production, because they retain more water and nutrients than sandy soils and have better drainage, aeration and tillage properties than clay soils.

ii) SOIL STRUCTURE

The primary soil particles viz., sand, silt and clay are usually grouped together in the form of aggregates. The arrangement of primary particles and their aggregates into certain defined patterns is called soil structure.

When soil particles are unattached to each other as in sandy soils, it is called single grained structure, Water percolates rapidly through this structure. When the soil is tightly packed in large cohesive blocks, as in case of dried clay, the structure is called massive. Water moves slowly through massive structured soils. Between these two extremes, an intermediate condition in which the soil particles are associated as aggregates. Organic matter acts as a binding agent for the soil particles. The shapes of aggregates found in the field can be classified as platy, prismatic or columnar, blocky, crumb or granular. The more favourable water relations are usually in soils that have prismatic, blocky and granular structures. Platy structure impedes the downward movement of water. In platy structure, the aggregates are arranged in relatively thin horizontal plates. Prismatic or columnar types are characterize by vertically oriented aggregates or pillars. In case of blocky the original aggregates have been reduced to blocks. In granular structure, the rounded complexes (usually less than 1/2 inch in diameter) usually lie loosely and are readily shaken apart.

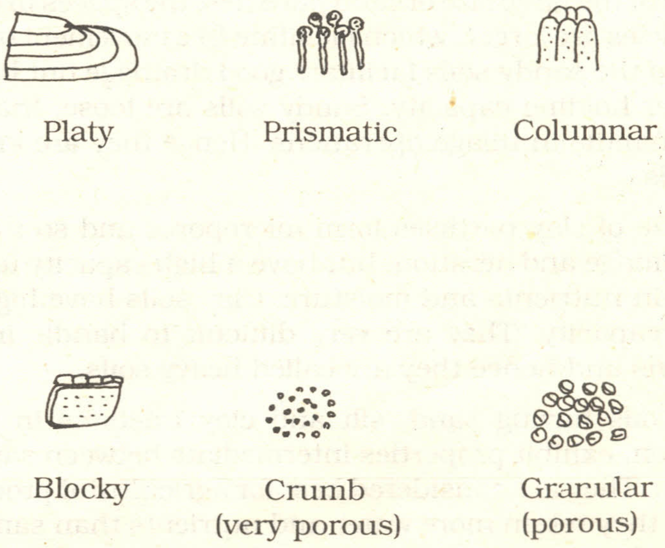

Fig. 2 Different structures of soil

Structure influences the rate at which water and air enter and move through the soil, it also affects root penetration and the soils nutrient supply. Structure of the surface soil can be changed, whereas soil texture is a permanent feature of soil and its change over years is negligible. Structure of the loose sandy soils can be improved by addition of organic matter which will act as a binding agent.

1.2 INTEXT QUESTION

1. Name the sources which supply carbon, hydrogen and oxygen to plant.
2. List the essential micronutrients for plant
3. What is a sandy soil?
4. Which of the following soils has higher water holding capacity?

   (a) Sandy soil (b) clay soil
5. Which soil structure impedes the downward movement of water?

iii) SOIL WATER

If you take wet soil and press it , some water will adhere to your palm. This water, as you have learnt, is present in the porespaces of soil. Therefore, the water held by the soil in its pore spaces is the soil water.

When water is added to a dry soil by either rain or irrigation, it is distributed around the soil particles where it is held by certain forces called soil moisture tension. The tenacity with which water is held by soil solids determines to a marked degree the movement of water in soils and its use by plants. When the moisture content of a soil is optimum for plant growth, plants can really assimilate the soil water, much of which is present in pores of intermediate size. As some of the moisture is removed by the growing plants, that which remains, is present in only the micro pores and as thin films around the soil particles. The attraction of the soil solids for this water is great, and they can compete successfully with higher plants for it. Consequently, not all the water that soils can hold is available to plants. Much of it remains in the soil after the plants have used some water and have wilted or even died as a consequence of water shortage.

The water from rain or irrigation displaces air in the soil pore spaces and eventually fills the pores. When all the pores - macro and micro - are filled with water, the soil is saturated and is at its **maximum retentive capacity.**

When the supply of water to the soil surface is cut off, the water in the macro pores then moves downward freely under the influence of gravity. The water thus removed from soil by the force of gravity is known as **free water or gravitational water.** The large (macro) pores are then filled with air, but the small (micro) pores have water in them. The water retained by the soil at this stage is called **field capacity.**

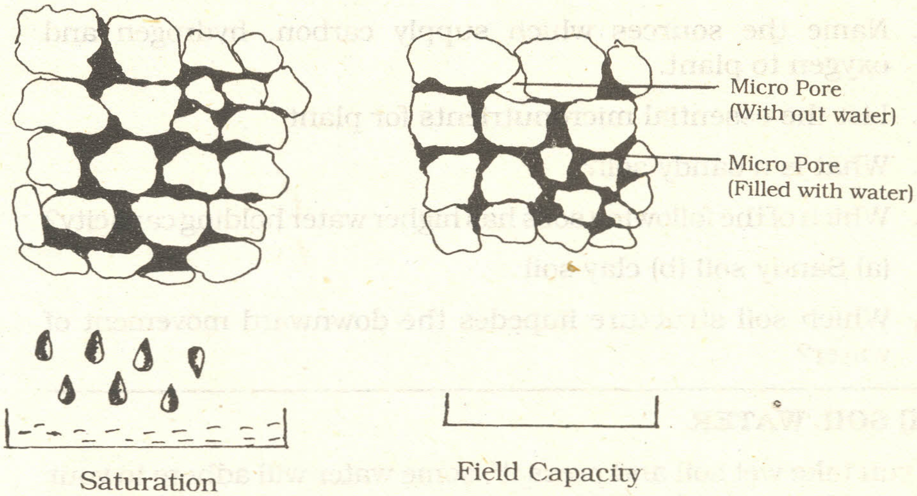

Fig. 3 Saturation and field capacity condition of soil.

Afterwards, the soil water is lost from soil surface as evaporation and from plant as transpiration. The plant absorbs water from soil by its roots and transpires major portion of water to the atmosphere through its stomata present in the leaves. The combined loss of soil water by evaporation and transpiration is known as evapotranspiration (E_T). Such loss of soil moisture reduces the amount of water in the soil to such an extent when plants no longer obtain enough moisture to meet the transpiration requirement of plant. As a result, the plant wilts and remains wilted permanently. The moisture content in soil when the plant permanently wilts is known as **permanent wilting point.** The plant can not absorb moisture further from soil due to much greater force of retention of water by soils.

You have learnt that water added to the soil is distributed around the soil particles where it is held by force. The **attraction** of the solid surfaces for water molecules is called adhesion and the attraction of water molecules for each other is known as **cohesion.** By adhesion, solids hold water molecules rigidly at their soil-water interfaces. These molecules in turn hold by cohesion other

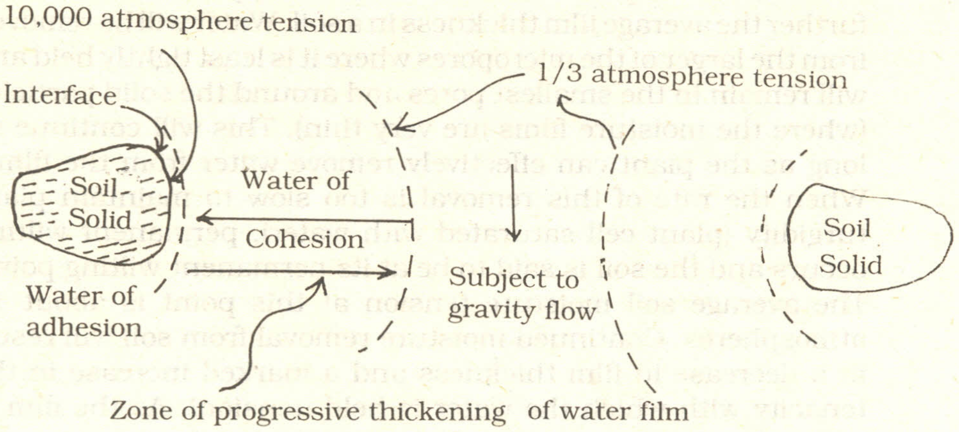

Fig.4 Progressive thickening of water film between two Soil particles

water molecules. Together, these forces make it possible for the soil solids to retain water and to control to a considerable degree its movement and utilization. Water held by these forces not only keep the micro pores entirely full of water but also maintain relatively thick films in the macropores. As these films thicken, they become progressively heavier and the moisture at the outer surface of the film less tenaciously held (fig. 4). This outer moisture is subject to ready movement in response to the pull of gravity and especially the pull of adjoining moisture films that are not so thick. Thus, when the soil is near saturation, it should be easy to remove a small increment of water. But as the moisture becomes less and less in soil, the greater and greater will be the force necessary to remove a unit amount.

Now let us examine the magnitude of force with which water is held in the soil at different moisture content in soil. You have learnt that soil moisture tension is the force with which water is held in the soil. It is generally expressed in atmospheric pressure. The relationship between film thickness and the energy of retention (soil moisture tension) at the outer edge of the moisture film is shown in Fig. 5. During heavy rain or irrigation even the macropores are essentially filled with water and the moisture films around and between solid particles are very thick. The tension with which the water is held at the edge of the film is very small. Consequently, some of the water held in these larger pores is pulled downward due to force of gravity. As the average film thickness decreases, the tension at the air-water interface increases and is finally great enough to drastically reduce the downward movement. Water has been removed from the macropores but is still present in the micropores. At this point (field capacity), the tension at the outer surface of the film is about 1/3 atmosphere. Utilization of water by plants will decrease further the average film thickness in a soil. Water will be removed from the larger of the micropores where it is least tightly held and will remain in the smallest pores and around the solid particles (where the moisture films are very thin). This will continue so long as the plant can effectively remove water from the films. When the rate of this removal is too slow to maintain plant turgidity (plant cell saturated with water), permanent wilting occurs and the soil is said to be at its permanent wilting point. The average soil moisture tension at this point is about 15 atmospheres. Continued moisture removal from soil will result in a decrease in film thickness and a marked increase in the tenacity with which the water is held (tension). As the film is progressively decreased in thickness, the tension increases to values as high as 10,000 atmospheres at soil-water interface (near soil particles).

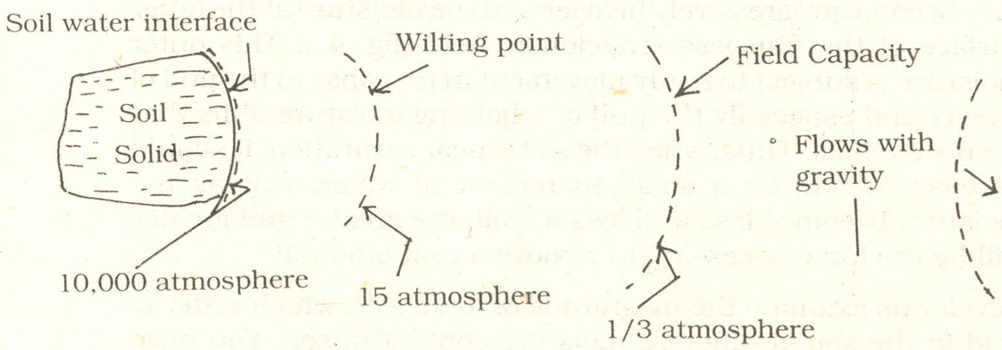

Fig.5 Relationship between thickness of water films and Soil moisture tension.

1.4 AVAILABLE WATER

The water held by the soil between field capacity (FC) and permanent wilting point (PWP) is considered as the available water for plants. Available water holding capacity (AWHC) of soil can be determined by subtracting the amount of moisture remaining in the soil at PWP from the amount held at FC. The water in soil above FC is drained away from soil due to force of gravity and water below PWP can not be removed by plant roots from soil. So water above FC and below PWP is not available to plants. Soil texture appreciably influences AWHC of soil. Sandy soils have very low AWHC, clay soils have very high AWHC, whereas silty and loamy soils have AWHC intermediate between sandy and clay soils (Table 1).

Table 1
Range of available water holding capacity of soils

Soil type cm	Depth of available water in per metre depth of soil
Fine sand	2 - 4
Sandy loam	4 - 11
Silt loam	6 - 13
Clay loam	10 - 18
Clay	16 - 13

1.3 INTEXT QUESTIONS

1. Define maximum retentive capacity of moisture in soil
2. What is adhesion?
3. What is the average soil moisture tension at permanent wilting point?
4. Which of the following soil water is available to plant?
   a) Water held between maximum retentive capacity and field capacity
   b) Water held between field capacity and permanent wilting point
   c) Water held between permanent wilting point and soil-water interface

WHAT YOU HAVE LEARNT

- Soil has solid, liquid, gaseous and living phases.
- Solid phase contains mineral matters and organic matters.
- Arrangement of soil particles creates spaces which are occupied by water, air and organisms.
- Liquid phase contains water and dissolved salts and plant nutrients. It supplies water and nutrients to plants.

- Gaseous phase supplies oxygen to the roots and soil organisms for respiration and their activities.
- Soil organisms of the living phase transform the nutrients into available form needed by plant.
- Soil acts as a storehouse of plant nutrients and also as a water reservoir.
- Soil texture and soil structure influence the rate at which water and air enter and move through the soil. They also affect the soil's nutrient supply.
- Water is held in soil with some force called soil moisture tension. It is expressed generally in atmosphere. Soil moisture tension increases with the decrease in soil moisture content in soil.
- Water above field capacity is drained due to force of gravity and is not available to plant. Water below permanent wilting point is held in soil very tenaciously and plant can not extract this moisture from soil and hence it is also not available to plant.

TERMINAL QUESTIONS

1. What are the four phases of soil? Discuss about the phase which consists of mineral components.
2. Write about the importance of liquid phase in the growth of plant.
3. How gaseous phase of soil differs from the atmospheric air?
4. What is soil texture? Discuss about the air-water relationship in a sandy soil.
5. Why clay soils are called heavy soils? Give the characteristics of such soils.
6. Define soil structure. Write about the water relations of different structure found in soil.
7. What is pore space? Discuss the importance of macro and micro pore spaces.
8. What is soil water? Define field capacity and permanent wilting point.
9. Define available water in soil for plant. Discuss available water holding capacity of different soil types.
10. Write short notes on
    a Soil as a store house of plant nutrients
    b. Soil as a habitat for organisms

11. Answer briefly
    a. From where root gets oxygen for respiration?
    b. Who convert plant's essential nutrients into available form in soil?
    c. Which of the two soils-clay and sandy-has good drainage facility?

ANSWERS TO INTEXT QUESTIONS

1.1 1. Solid phase, liquid phase, gaseous phase and living phase.
2. (b)
3. aD, bA,cC, dB

1.2 1. Water and atmosphere
2. Iron, Manganese, Copper, Zinc, Boron, Molybdenum and Chlorine.
3. Soil with more than 70% sand particles is sandy soil.
4. (b)
5 Platy

1.3 1. When all the macro and micro pores of soil are filled with water the soil is at its maximum retentive capacity.
2. The attraction of the solid surface for water molecules is calaled adhesion.
3. 15 atmosphere
4. (b)

SUGGESTED READINGS

1. Nature & Properties of Soil - Buckman & Brady
2. Irrigation Theory & Practices - A.M. Michael.