

- Soil forming processes and weathering depend on water
- Microorganisms require water for their metabolic activities
- Soil water helps in chemical and biological activities of soil
- It is a principal constituent of the growing plant
- Water is essential for photosynthesis

Water serves four functions in plants:

- it is the major constituents of plant protoplasm(85-95%)
- it is essential for photosynthesis and conversion of starches to sugars
- it is the solvent in which nutrients move into and through plant parts to capture sunlight.
- In fact, the soil water is a great regulator of physical, chemical and biological activities in the soil.

Plants absorb some water through leaf stomata (openings), but most of the water used by plants is absorbed by the roots from the soil. For optimum water used, it is vital to know how water moves into and through the soil, how the soil stores water, how the plant absorbs it, how nutrients are lost from the soil by percolation, and how to measure soil water content and losses.

Soil also serves as a regulated reservoir for water because it receives precipitation and irrigation water.

A representative cultivated loam soil contains approximately 50% solid particles (sand, silt, clay and organic matter), 25% air and the rest 25%water.only half of this water is available to plants because of the mechanics of water storage in the soil.

Structure of water

Water can participate in a series of reactions occurring in soils and plants, only because of its structural behavior. Water is simple compound, its individual molecules containing one oxygen atom and two much smaller hydrogen atoms.

The elements are bonded together covalently, each hydrogen or proton sharing its single electron with the oxygen. Instead of the atoms being arranged linearly (H-O-H) the hydrogen atoms are attached to the oxygen as a v shaped.

Factors Affecting Soil Water

- 1. Texture:** Finer the texture, more is the pore space and also surface area, greater is the retention of water.
- 2. Structure:** Well-aggregated porous structure favors better porosity, which in turn enhance water retention.
- 3. Organic matter:** Higher the organic matter more is the water retention in the soil.
- 4. Density of soil:** Higher the density of soil, lower is the moisture content.
- 5. Temperature:** Cooler the temperature, higher is the moisture retention.
- 6. Salt content:** More the salt content in the soil less is the water available to the plant.
- 7. Depth of soil:** More the depth of soil more is the water available to the plant.
- 8. Type of clay:** The 2:1 type of clay increases the water retention in the soil.

Classification of soil water

Soil water has been classified from a physical and biological point of view as Physical classification of soil water, and biological classification of soil water.

Physical classification of soil water

i) Gravitational water ii) Capillary water and iii) Hygroscopic water

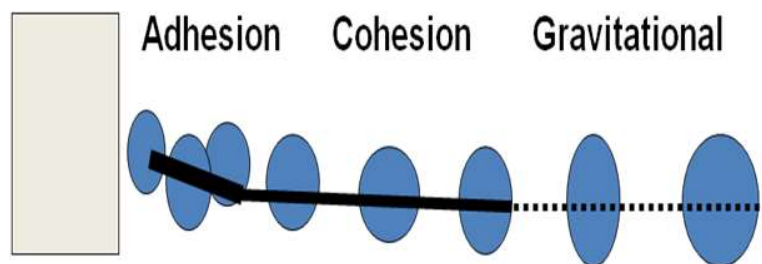
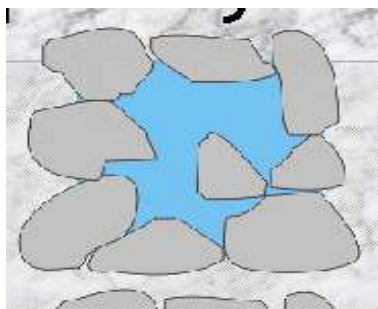
1. Gravitational water: Gravitational water occupies the larger soil pores (macro pores) and moves down readily under the force of gravity. Water in excess of the field capacity is termed gravitational water. Gravitational water is of no use to plants because it occupies the larger pores. It reduces aeration in the soil. Thus, its

removal from soil is a requisite for optimum plant growth. Soil moisture tension at gravitational state is zero or less than $\frac{1}{3}$ atmosphere.

Factors affecting gravitational water

i. Texture: Plays a great role in controlling the rate of movement of gravitational water. The flow of water is proportional to the size of particles. The bigger the particle, the more rapid is the flow or movement. Because of the larger size of pore, water percolates more easily and rapidly in sandy soils than in clay soils.

ii. Structure: It also affects gravitational water. In platy structure movement of gravitational water is slow and water stagnates in the soil. Granular and crumbly structure helps to improve gravitational water movement. In clay soils having single grain structure, the gravitational water, percolates more slowly. If clay soils form aggregates (granular structure), the movement of gravitational water improves.



2. Capillary water: Capillary water is held in the capillary pores (micro pores). Capillary water is retained on the soil particles by surface forces. It is held so strongly that gravity cannot remove it from the soil particles. The molecules of capillary water are free and mobile and are present in a liquid state. Due to this reason, it evaporates easily at ordinary temperature though it is held firmly by the soil particle; plant roots are able to absorb it. Capillary water is, therefore, known as available water. The capillary water is held between $\frac{1}{3}$ and 31 atmosphere pressure.

Factors affecting capillary water

The amount of capillary water that a soil is able to hold varies considerably. The following factors are responsible for variation in the amount of capillary water.

i. Surface tension: An increase in surface tension increases the amount of capillary water.

ii. Soil texture: The finer the texture of a soil, greater is the amount of capillary water holds. This is mainly due to the greater surface area and a greater number of micro pores.

iii. Soil structure: Platy structure contains more water than granular structure.

iv. Organic matter: The presence of organic matter helps to increase the capillary capacity of a soil. Organic matter itself has a great capillary capacity. Undecomposed organic matter is generally porous having a large surface area, which helps to hold more capillary water. The humus that is formed on decomposition has a great capacity for absorbing and holding water. Hence the presence of organic matter in soil increases the amount of capillary water in soil.

3. Hygroscopic water: The water that held tightly on the surface of soil colloidal particle is known as hygroscopic water. It is essentially non-liquid and moves primarily in the vapour form.

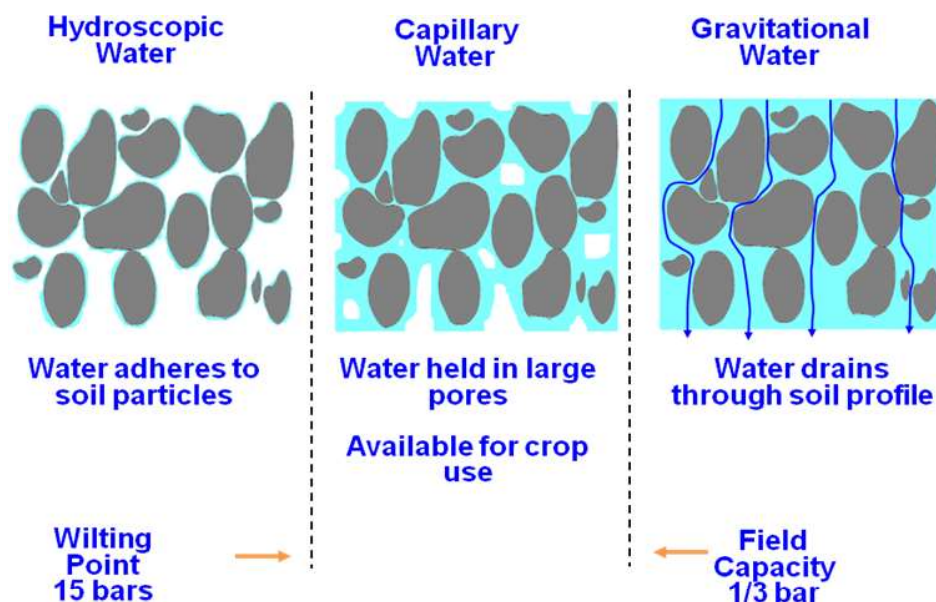
Hygroscopic water held so tenaciously {31 to 10000 atmosphere) by soil particles that plants cannot absorb it. Some microorganism may utilize hygroscopic water. As hygroscopic water is held tenaciously by surface forces its removal from the soil requires a certain amount of energy. Unlike capillary water which evaporates easily at atmospheric temperature, hygroscopic water cannot be separated from the soil unless it is heated

Factors affecting hygroscopic water:

Hygroscopic water is held on the surface of colloidal particles by the dipole orientation of water molecules. The amount of hygroscopic water varies inversely

with the size of soil particles. The smaller the particle, the greater is the amount of hygroscopic water it adsorbs.

Fine textured soils like clay contain more hygroscopic water than coarse - textured soils. The amount of clay and also its nature influences the amount of hygroscopic water. Clay minerals of the montmorillonite type with their large surface area adsorb more water than those of the kaolinite type, while illite minerals are intermediate.



B. Biological Classification of Soil Water: There is a definite relationship between moisture retention and its utilization by plants. This classification based on the availability of water to the plant. Soil moisture can be divided into three parts.

i. Available water: The water which lies between wilting coefficient and field capacity. It is obtained by subtracting wilting coefficient from moisture equivalent.

ii. Unavailable water: This includes the whole of the hygroscopic water plus a part of the capillary water below the wilting point.

iii. Super available or superfluous water: The water beyond the field capacity stage is said to be super available. It includes gravitational water plus a part of the capillary water removed from larger interstices. This water is unavailable for the use of plants. The presence of super-available water in a soil for any extended period is harmful to plant growth because of the lack of air.

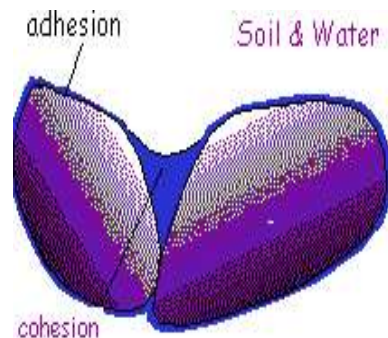
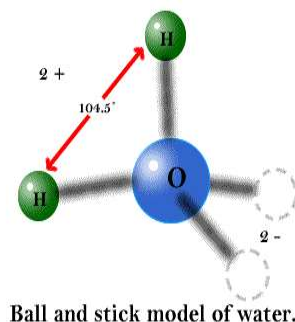
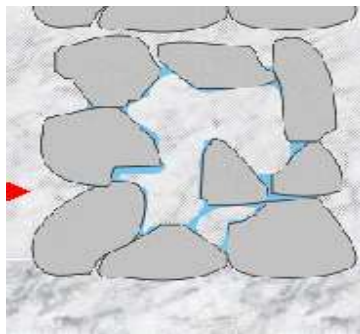
Retention of Water by Soil

The soils hold water (moisture) due to their colloidal properties and aggregation qualities. The water is held on the surface of the colloids and other particles and in the pores. The forces responsible for retention of water in the soil after the drainage has stopped are due to surface tension and surface attraction and are called surface moisture tension. This refers to the energy concept in moisture retention relationships. The force with which water is held is also termed as suction.

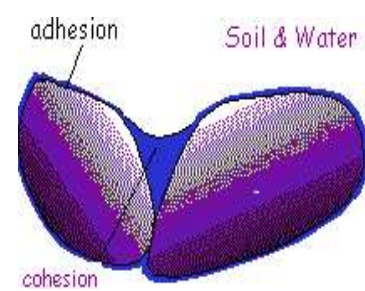
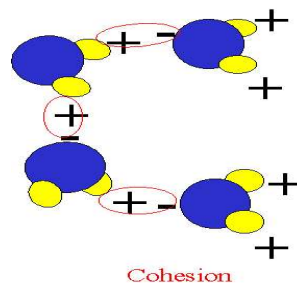
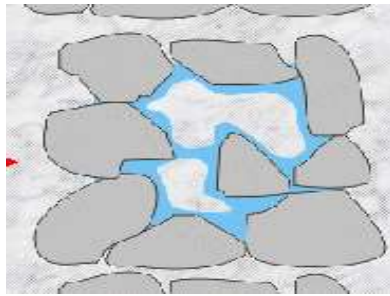
The water retained in the soil by following ways

1. Cohesion and adhesion forces: These two basic forces are responsible for water retention in the soil. One is the attraction of molecules for each other i.e., cohesion. The other is the attraction of water molecules for the solid surface of soil i.e. adhesion. By adhesion, solids (soil) hold water molecules rigidly at their soil - water interfaces. These water molecules in turn hold by cohesion. Together, these forces make it possible for the soil solids to retain water.

Adhesion



Cohesion



2. Surface tension: This phenomenon is commonly evidenced at water- air interfaces. Water behaves as if its surface is covered with a stretched elastic membrane. At the surface, the attraction of the air for the water molecules is much less than that of water molecules for each other. Consequently, there is a net downward force on the surface molecules, resulting in sort of a compressed film (membrane) at the surface. This phenomenon is called surface tension.

3. Polarity or dipole character: The retention of water molecules on the surface of clay micelle is based on the dipole character of the molecule of water. The water molecules are held by electrostatic force that exists on the surface of colloidal particles. By virtue of their dipole character and under the influence of electrostatic forces, the molecules of water get oriented (arranged) on the surface of the clay particles in a particular manner.

Each water molecule carries both negative and positive charges. The clay particle is negatively charged. The positive end of water molecule gets attached to the negatively charged surface of clay and leaving its negative end outward. The water molecules attached to the clay surface in this way present a layer of negative charges to which another layer of oriented water molecules is attached. The number of successive molecular layers goes on increasing as long as the water molecules oriented. As the molecular layer gets thicker, orientation becomes weaker, and at a certain distance from the particle surface the water molecules cease to orientate and capillary water (liquid water) begins to appear. Due to the

forces of adsorption (attraction) exerted by the surface of soil particles, water gets attached on the soil surface. The force of gravity also acts simultaneously, which tries to pull it downwards. The surface force is far greater than the force of gravity so water may remain attached to the soil particle. The water remains attached to the soil particle or move downward into the lower layers, depending on the magnitude of the resultant force.

Potentials

Soil water potential:

The retention and movement of water in soils, its uptake and translocation in plants and its loss to the atmosphere are all energy related phenomenon. The more strongly water is held in the soil the greater is the heat (energy) required. In other words, if water is to be removed from a moist soil, work has to be done against adsorptive forces. Conversely, when water is adsorbed by the soil, a negative amount of work is done. The movement is from a zone where the free energy of water is high (standing water table) to one where the free energy is low (a dry soil). This is called soil water energy concept.

Free energy of soil solids for water is affected by:

i) Matric (solid) force i.e., the attraction of the soil solids for water (adsorption) which markedly reduces the free energy (movement) of the adsorbed water molecules.

ii) Osmotic force i.e., the attraction of ions and other solutes for water to reduce the free energy of soil solution.

Matric and Osmotic potentials are negative and reduce the free energy level of the soil water. These negative potentials are referred as suction or tension.

iii) Force of gravity: This acts on soil water, the attraction is towards the earth's center, which tends to pull the water downward. This force is always positive. The

difference between the energy states of soil water and pure free water is known as soil water potential. **Total water potential** (Pt) is the sum of the contributions of **gravitational potential** (Pg), **matric potential** (Pm) and the **Osmotic potential** or **solute potential** (Po).

$$P_t = P_g + P_m + P_o$$

Potential represents the difference in free energy levels of pure water and of soil water. The soil water is affected by the force of gravity, presence of soil solid (matric) and of solutes.

Soil moisture constants

Earlier classification divided soil water into gravitational, capillary and hygroscopic water. The hygroscopic and capillary waters are in equilibrium with the soil under given condition. The hygroscopic coefficient and the maximum capillary capacity are the two equilibrium points when the soil contains the maximum amount of hygroscopic and capillary waters, respectively. The amount of water that a soil contains at each of these equilibrium points is known as soil moisture constant.

The soil moisture constant, therefore, represents definite soil moisture relationship and retention of soil moisture in the field.

The three classes of water (gravitational, capillary and hygroscopic) are however very broad and do not represent accurately the soil - water relationships that exists under field conditions.

Though the maximum capillary capacity represents the maximum amount of capillary water that a soil holds, the whole of capillary water is not available for the use of the plants. A part of it, at its lower limit approaching the hygroscopic coefficient is not utilized by the plants. Similarly a part of the capillary water at its upper limit is also not available for the use of plants. Hence two more soil constants, viz., field capacity and wilting coefficient have been introduced to

express the soil-plant-water relationships as it is found to exist under field conditions.

1. Field capacity: Assume that water is applied to the surface of a soil. With the downward movement of water all macro and micro pores are filled up. The soil is said to be saturated with respect to water and is at maximum water holding capacity or maximum retentive capacity. It is the amount of water held in the soil when all pores are filled. Sometimes, after application of water in the soil all the gravitational water is drained away, and then the wet soil is almost uniformly moist. The amount of water held by the soil at this stage is known as the field capacity or normal moisture capacity of that soil. **It is the capacity of the soil to retain water against the downward pull of the force of gravity. At this stage only micropores or capillary pores are filled with water and plants absorb water for their use. At field capacity water is held with a force of $1/3$ atmosphere. Water at field capacity is readily available to plants and microorganism.**

2. Wilting coefficient: As the moisture content falls, a point is reached when the water is so firmly held by the soil particles that plant roots are unable to draw it. The plant begins to wilt. At this stage even if the plant is kept in a saturated atmosphere it does not regain its turgidity and wilts unless water is applied to the soil. The stage at which this occurs is termed the Wilting point and the percentage amount of water held by the soil at this stage is known as the Wilting Coefficient. It represents the point at which the soil is unable to supply water to the plant. Water at wilting coefficient is held with a force of 15 atmosphere.

3. Hygroscopic coefficient: The hygroscopic coefficient is the maximum amount of hygroscopic water absorbed by 100 g of dry soil under standard conditions of humidity (50% relative humidity) and temperature (15°C). This tension is equal to

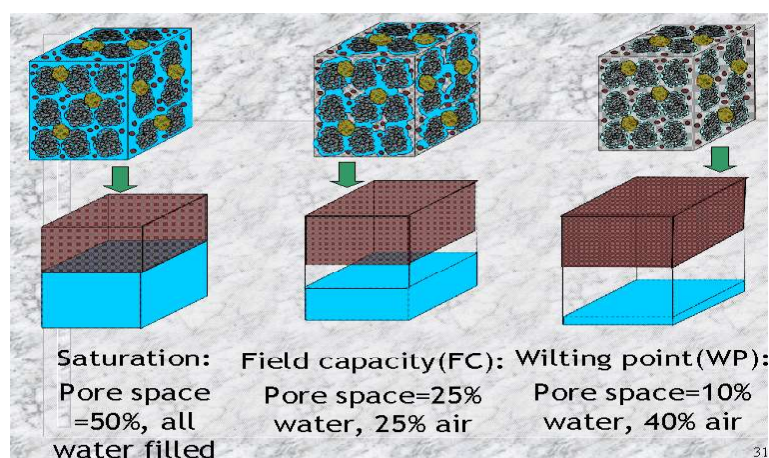
a force of 31 atmospheres. Water at this tension is not available to plant but may be available to certain bacteria.

4. Available water capacity: The amount of water required to apply to a soil at the wilting point to reach the field capacity is called the "available" water. The water supplying power of soils is related to the amount of available water a soil can hold. The available water is the difference in the amount of water at field capacity (- 0.3 bar) and the amount of water at the permanent wilting point (- 15 bars).

5. Maximum water holding capacity: It is also known as maximum retentive capacity. It is the amount of moisture in a soil when its pore spaces both micro and macro capillary are completely filled with water. It is a rough measure of total pore space of soil. Soil moisture tension is very low between $1/100^{\text{th}}$ to $1/1000^{\text{th}}$ of an atmosphere or pF 1 to 0.

6. Sticky point moisture: It represents the moisture content of soil at which it no longer sticks to a foreign object. The sticky point represents the maximum moisture content at which a soil remains friable. Sticky point moisture values vary nearly approximate to the moisture equivalent of soils. Summary of the soil moisture constants, type of water and force with which it held is given in following table.

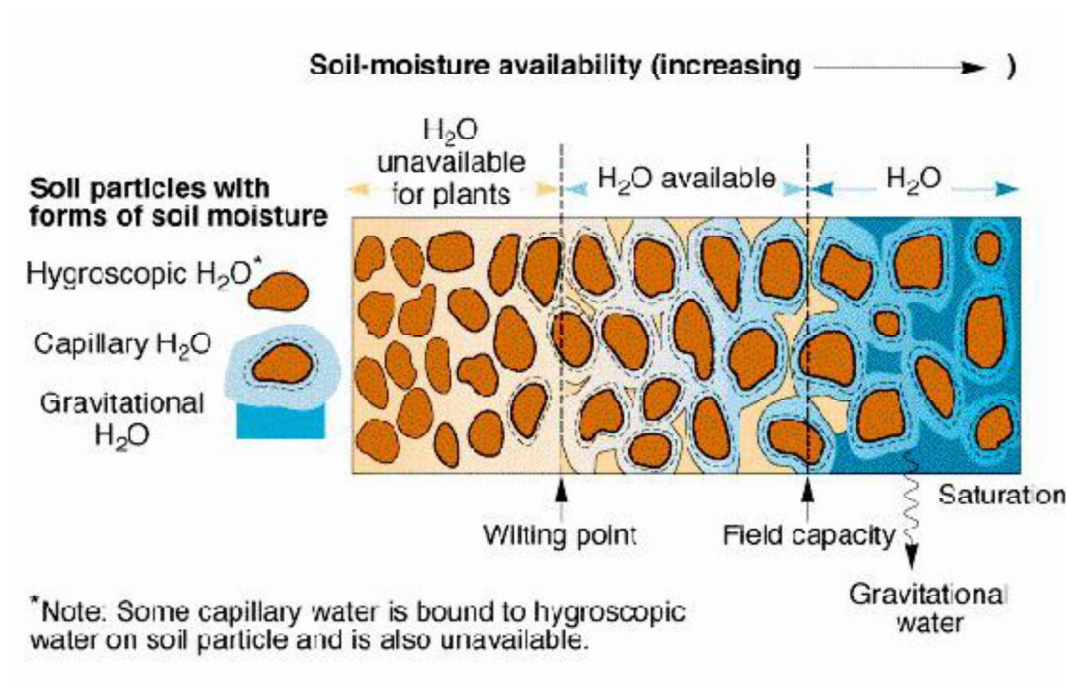
Soil water capacity



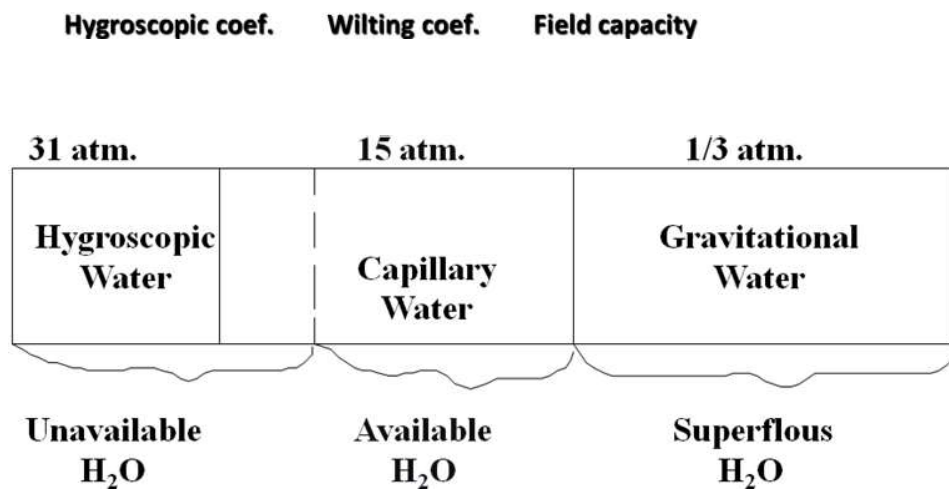
Moisture equivalent : It is defined as the percentage of water held by one centimeter thick moist layer of soil subjected to a centrifugal force of 1000 times of gravity for half an hour.

Soil moisture constants and range of tension and pF

S.No.	Moisture class	Tension (atm)	pF
1	Chemically combined	Very high	---
2	Water vapour	Held at saturation point in the soil air	---
3	Hygroscopic	31 to 10,000	4.50 to 7.00
4	Hygroscopic coefficient	31	4.50
5	Wilting point	15	4.20
6	Capillary	1/3 to 31	2.54 to 4.50
	Moisture equivalent	1/3 to 1	2.70 to 3.00
	Field capacity	1/3	2.54
	Sticky point	1/3 (more or less)	2.54
	Gravitational	Zero or less than 1/3	<2.54
	Maximum water holding capacity	Almost zero	---



Relationship between soil moisture and tension



Movement of soil water- Infiltration, percolation, permeability – Drainage -

Methods of determination of soil moisture –

Soil Water Movement

- i) Saturated Flow
- ii) Unsaturated Flow
- iii) Water Vapour Movement

Saturated flow: This occurs when the soil pores are completely filled with water. This water moves at water potentials larger than -33 kPa. Saturated flow is water flow caused by gravity's pull. It begins with *infiltration*, which is water movement into soil when rain or irrigation water is on the soil surface. When the soil profile is wetted, the movement of more water flowing through the wetted soil is termed percolation.

Hydraulic conductivity can be expressed mathematically as

$$V = kf$$

Where,

V = Total volume of water moved per unit time

f = Water moving force

k = Hydraulic conductivity of soil

Factors affecting movement of water

1. Texture, 2. Structure, 3. Amount of organic matter, 4. Depth of soil to hard pan, 5. Amount of water in the soil, 6. temperature and 7. Pressure

Vertical water flow

The vertical water flow rate through soil is given by *Darcy's law*. The law states that the rate of flow of liquid or flux through a porous medium is proportional to the hydraulic gradient in the direction of flow of the liquid.

$(dw) At$

$$QW = - k (dw) At / Ds$$

Where,

QW = Quantity of water in cm^{-1}

k = rate constant (cm/s)

dw = Water height (head), cm

A = Soil area (cm^2)

t = Time

ds = Soil depth (cm)

(ii) Unsaturated Flow

It is flow of water held with water potentials lower than- 1/3 bar. Water will move toward the region of lower potential (towards the greater “pulling” force). In a uniform soil this means that water moves from wetter to drier areas. The water movement may be in any direction. The rate of flow is greater as the water potential gradient (the difference in potential between wet and dry) increases and as the size of water filled pores also increases. The two forces responsible for this movement are the attraction of soil solids for water (adhesion) and capillarity. Under field conditions this movement occurs when the soil macropores (non-capillary) pores with filled with air and the micropores (capillary) pores with water and partly with air.

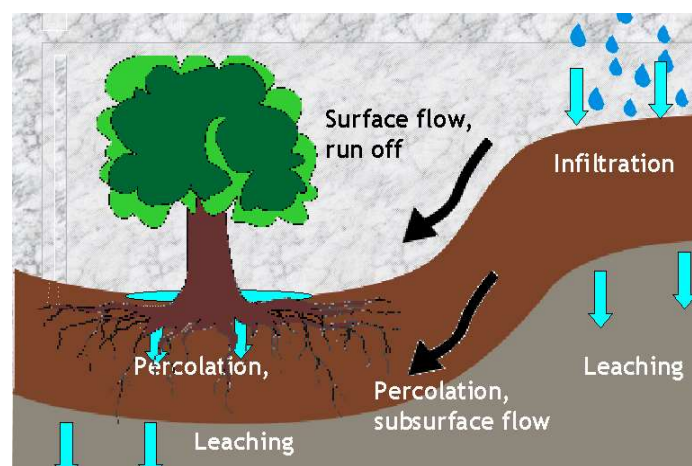
Factors Affecting the Unsaturated Flow

Unsaturated flow is also affected in a similar way to that of saturated flow. Amount of moisture in the soil affects the unsaturated flow. The higher the percentage of water in the moist soil, the greater is the suction gradient and the more rapid is the delivery.

(iii) Water Vapour Movement

The movement of water vapour from soils takes place in two ways: (a) Internal movement—the change from the liquid to the vapour state takes place within the soil, that is, in the soil pores and (b) External movement—the phenomenon occurs at the land surface and the resulting vapour is lost to the atmosphere by diffusion and convection.

The movement of water vapour through the diffusion mechanism taken place from one area to other soil area depending on the vapour pressure gradient (moving force). This gradient is simply the difference in vapour pressure of two points a unit distance apart. The greater this difference, the more rapid the diffusion and the greater is the transfer of water vapour during a unit period.



Soil conditions affecting water vapour movement:

There are mainly two soil conditions that affect the water vapour movement namely moisture regimes and thermal regimes. In addition to these, the various other factors which influence the moisture and thermal regimes of the soil like organic matter, vegetative cover, soil colour etc. also affect the movement of water vapour. The movement takes place from moist soil having high vapour pressure to a dry soil (low vapour pressure). Similarly the movement takes place from warmer soil regions to cooler soil region. In dry soils some water movement takes place in

the vapour form and such vapour movement has some practical implications in supplying water to drought resistant plants.

Entry of Water into Soil

Infiltration: Infiltration refers to the downward entry or movement of water into the soil surface

- ❖ It is a surface characteristic and hence primarily influenced by the condition of the surface soil.
- ❖ Soil surface with vegetative cover has more infiltration rate than bare soil
- ❖ Warm soils absorb more water than colder ones
- ❖ Coarse surface texture, granular structure and high organic matter content in surface soil, all help to increase infiltration
- ❖ Infiltration rate is comparatively lower in wet soils than dry soils

Factors affecting infiltration

- i. Clay minerals
- ii. Soil Texture
- iii. Soil structure
- iv. Moisture content
- v. Vegetative cover
- vi. Topography

Percolation: The movement of water through a column of soil is called percolation. It is important for two reasons.

- i) This is the only source of recharge of ground water which can be used through wells for irrigation
- ii) Percolating waters carry plant nutrients down and often out of reach of plant roots (leaching)
 - ❖ In dry region it is negligible and under high rainfall it is high

- ❖ Sandy soils have greater percolation than clayey soil
- ❖ Vegetation and high water table reduce the percolation loss

Permeability: It indicates the relative ease of movement of water within the soil. The characteristics that determine how fast air and water move through the soil is known as permeability. The term hydraulic conductivity is also used which refers to the readiness with which a soil transmits fluids through it

Drainage

The frequency and duration of periods when the soil is free from saturation with water. It controls the soil cum water relationship and the supply of nutrients to the plants.

Drainage class

Very poorly drained

Poorly drained

Imperfect

Moderately well

Well

Somewhat excessive

Excessive

Hysteresis

The moisture content at different tensions during wetting of soil varies from the moisture content at same tensions during drying. This effect is called as hysteresis. This is due to the presence of capillary and non capillary pores. The moisture content is always low during sorption and high during desorption. Hysteresis phenomenon exists in soil minerals as a consequence of shrinking and swelling. Shrinking and swelling affect pore size on a microbasis as well as on the basis of overall bulk density. So, hysteresis phenomenon occurs due to factors like shape and size of soil pores and their interconnection with each other pore configuration,

nature of soil colloids bulk density of soil and entrapped air. The most important factor affecting hysteresis is the entrapment of air in the soil under rewetting condition. This clogs some pores and prevent effective contact between others.

Methods of determination of soil moisture

Two general types of measurements relating to soil water are ordinarily used

- i) By some methods the moisture content is measured directly or indirectly
- ii) Techniques are used to determine the soil moisture potential (tension or suction)

Measuring soil moisture content in laboratory

1. Gravimetric method: This consists of obtaining a moist sample, drying it in an oven at 105°C until it losses no more weight and then determining the percentage of moisture. The gravimetric method is time consuming and involves laborious processes of sampling, weighing and drying in laboratory.

2. Electrical conductivity method: This method is based upon the changes in electrical conductivity with changes in soil moisture. Gypsum blocks inside of with two electrodes at a definite distance are apart used in this method. These blocks require previous calibration for uniformity. The blocks are buried in the soil at desired depths and the conductivity across the electrodes measured with a modified Wheatstone bridge. These electrical measurements are affected by salt concentration in the soil solution and are not very helpful in soils with high salt contents.

Measuring soil moisture potential insitu (field)

Suction method or equilibrium tension method: Field tensiometers measure the tension with which water is held in the soils. They are used in determining the need for irrigation. The tensiometer is a porous cup attached to a glass tube, which is

connected to a mercury monometer. The tube and cup are filled with water and cup inserted in the soil. The water flows through the porous cup into the soil until equilibrium is established. These tension readings in monometer, expressed in terms of cm or atmosphere, measures the tension or suction of the soil.

If the soil is dry, water moves through the porous cup, setting up a negative tension (or greater is the suction). The tensiometers are more useful in sandy soils than in fine textured soils. Once the air gets entrapped in the tensiometer, the reliability of readings is questionable.

Thermal properties of soils – Soil temperature – Soil air – Gaseous exchange –

Influence of soil temperature and air on plant growth –

Thermal properties of soils

The thermal properties of soils are a component of soil physics that has found important uses in engineering, climatology and agriculture. These properties influence how energy is partitioned in the soil profile. While related to soil temperature, it is more accurately associated with the transfer of heat throughout the soil, by radiation, conduction and convection.

Main soil thermal properties:

Volumetric heat capacity, SI units: $\text{Jm}^{-3}\text{K}^{-1}$

Thermal conductivity, SI units: $\text{W.m}^{-1}\text{K}^{-1}$

Thermal diffusivity, SI units: $\text{m}^2.\text{s}^{-1}$

Soil temperature – Soil air – Gaseous exchange

Soil Temperature

Soil temperature is an important plant growth factor like air, water and nutrients. Soil temperature affects plant growth directly and also indirectly by influencing moisture, aeration, structure, microbial and enzyme activities, rate of organic matter decomposition, nutrient availability and other soil chemical reactions. Specific crops are adapted to specific soil temperatures. Apple grows well when the soil temperature is about 18°C , maize 25°C , potato 16 to 21°C , and so on.

Sources of soil heat

The sources of heat for soil are solar radiation (external), heat released during microbial decomposition of organic matter and respiration by soil organisms including plants and the internal source of heat is the interior of the

Earth - which is negligible. The rate of solar radiation reaching the earth's atmosphere is called as solar constant and has a value of $2 \text{ cal cm}^{-2} \text{ min}^{-1}$. Major part of this energy is absorbed in the atmosphere, absorbed by plants and also scattered. Only a small part of it reaches soil. Thermal energy is transmitted in the form of thermal infrared radiation from the sun across the space and through the atmosphere.

Factors affecting soil temperature

The average annual soil temperature is about 1°C higher than mean annual air temperature. Soil temperature is influenced by climatic conditions. The factors that affect the transfer of heat through the atmosphere from sun affect the soil temperature also.

Environmental factors

Solar radiation: The amount of heat received from sun on Earth's surface is $2 \text{ cal cm}^{-2} \text{ min}^{-1}$. But the amount of heat transmitted into soil is much lower. The heat transmission into soil depends on the angle of incident radiation, latitude, season, time of the day, steepness and direction of slope and altitude. The insulation by air, water vapour, clouds, dust, smog, snow, plant cover, mulch *etc.*, reduces the amount of heat transferred into soil.

Soil factors

a) Thermal (Heat) capacity of soil: The amount of energy required to raise the temperature by 1°C is called *heat capacity*. When it is expressed per unit mass (Calories per gram), then it is called as *specific heat*. The specific heat of water is 1.00 cal g^{-1} where the specific heat of a dry soil is 0.2 cal g^{-1} . Increasing water content in soil increases the specific heat of the soil and hence a dry soil heats up quickly than a moist soil.

b) Heat of vaporization: The evaporation of water from soil requires a large amount of energy, 540 kilocalories kg^{-1} soil. Soil water utilizes the energy from solar radiation to evaporate and thereby rendering it unavailable for heating up of soil. Also the thermal energy from soil is utilized for the evaporation of water, thereby reducing the soil temperature. This is the reason that surface soil temperatures will be sometimes 1 to 6°C lower than the sub-surface soil temperature. That is why the specific heat of a wet soil is higher than dry soil.

c) Thermal conductivity and diffusivity: This refers to the movement of heat in soils. In soil, heat is transmitted through conduction. Heat passes from soil to water about 150 times faster than soil to air. So the movement of heat will be more in wet soil than in dry soil where the pores will be occupied with air. Thermal conductivity of soil forming materials is 0.005 thermal conductivity units, and that of air is 0.00005 units, water 0.001 units. A dry and loosely packed soil will conduct heat slower than a compact soil and wet soil.

d) Biological activity: Respiration by soil animals, microbes and plant roots evolve heat. More the biological activity more will be the soil temperature.

e) Radiation from soil: Radiation from high temperature bodies (Sun) is in short waves (0.3 to 2.2 μ) and that from low temperature bodies (soil) is in long waves (6.8 to 100 μ) Longer wavelengths have little ability to penetrate water vapour, air and glass and hence soil remains warm during night hours, cloudy days and in glass houses.

f) Soil colour: Colour is produced due to reflection of radiation of specific wavelengths. Dark coloured soils radiate less heat than bright coloured soils. The ratio between the incoming (incident energy) and outgoing (reflected energy) radiation is called *albedo*. The larger the albedo, the cooler is the soil. Rough surfaced soil absorbs more solar radiation than smooth surface soils.

$$\text{Albedo} = \frac{\text{Reflected energy}}{\text{Incident energy}}$$

g) Soil structure, texture and moisture: Compact soils have higher thermal conductivity than loose soils. Natural structures have high conductivity than disturbed soil structures. Mineral soils have higher conductivity than organic soils. Moist soil will have uniform temperature over depth because of its good conductivity than dry soils.

h) Soluble salts: Indirectly affects soil temperature by influencing the biological activities, evaporation *etc.*

Soil Air

Soil air is a continuation of the atmospheric air. Unlike the other components, it is constant state of motion from the soil pores into the atmosphere and from the atmosphere into the pore space. This constant movement or circulation of air in the soil mass resulting in the renewal of its component gases is known as soil aeration. .

Composition of Soil Air: The soil air contains a number of gases of which nitrogen, oxygen, carbon dioxide and water vapour are the most important. Soil air constantly moves from the soil pores into the atmosphere and from the atmosphere into the pore space. Soil air and atmospheric air differ in the compositions. Soil air contains a much greater proportion of carbon dioxide and a lesser amount of oxygen than atmospheric air. At the same time, soil air contains a far great amount of water vapour than atmospheric air. The amount of nitrogen in soil air is almost the same as in the atmosphere.

Composition of soil and atmospheric air

Percentage by volume

Nitrogen	Oxygen	Carbon
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dioxide			
Soil air	79.2	20.60	0.30
Atmospheric air	79.9	20.97	0.03

Factors Affecting the Composition of Soil Air:

1. Nature and condition of soil: The quantity of oxygen in soil air is less than that in atmospheric air.

The amount of oxygen also depends upon the soil depth.

The oxygen content of the air in lower layer is usually less than that of the surface soil. This is possibly due to more readily diffusion of the oxygen from the atmosphere into the surface soil than in the subsoil.

Light texture soil or sandy soil contains much higher percentage than heavy soil.

The concentration of CO_2 is usually greater in subsoil probably due to more sluggish aeration in lower layer than in the surface soil.

2. Type of crop: Plant roots require oxygen, which they take from the soil air and deplete the concentration of oxygen in the soil air. Soils on which crops are grown contain more CO_2 than fallow lands. The amount of CO_2 is usually much greater near the roots of plants than further away. It may be due to respiration by roots.

3. Microbial activity: The microorganisms in soil require oxygen for respiration and they take it from the soil air and thus deplete its concentration in the soil air. Decomposition of organic matter produces CO_2 because of increased microbial activity. Hence, soils rich in organic matter contain higher percentage of CO_2 .

4. Seasonal variation: The quantity of oxygen is usually higher in dry season than during the monsoon. Because soils are normally drier during the summer months, opportunity for gaseous exchange is greater during this period. This results in relatively high O_2 and low CO_2 levels. Temperature also influences the CO_2 content in the soil air. High temperature during summer season encourages microorganism activity which results in higher production of CO_2 .

Exchange of Gases between Soil and Atmosphere