LECTURE 03

Soil Water Components

- Soil is a heterogeneous mass consisting of a three phase system of solid, liquid and gas. Mineral matter, consisting of sand, silt and clay and organic matter form the largest fraction of soil and serves as a framework (matrix) with numerous pores of various proportions.

- Soil serves as a storage reservoir for nutrients and water needed for plant growth.

- Soil is a complex mass of mineral and organic particles. The important properties (physical and chemical) that classify soil according to its relevance to making crop production are:

- Soil texture

- Soil structure

- Depth of Soil

Soil texture:

- This refers to the relative sizes of soil particles in a given soil.
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- According to their sizes, soil particles are grouped into gravel, sand, silt and clay.
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- The relative proportions of sand, silt and clay is a soil mass determines the soil texture.

According to textural gradations a soil may be broadly classified as:

- Open or light textural soils: these are mainly coarse or sandy with low content of silt and clay.

- Medium textured soils: these contain sand, silt and clay in sizeable proportions, like loamy soil.

- Tight or heavy textured soils: these contain high proportion of clay.

Soil structure:

- This refers to the arrangement of soil particles and aggregates with respect to each other.
- Aggregates are groups of individual soil particles adhering together.
- Soil structure is recognized as one of the most important properties of soil mass, since it influences aeration, permeability, water holding capacity, etc.

Depth of Soil

- It is very important for having adequate depth of soil for storing sufficient amount of irrigation water and providing space for root penetartion
- Shallow soils require more frequent irrigation whereas deep soil require less frequent irrigation

Chemical properties

- For enhancing crop yield, soils must have sufficient plant nutrients such as nitrogen, carbon, hydrogen, iron, oxygen, potassium, phosphorus, sulphur, magnesium etc. Nitrogen is the most important of all the nutrients.
- Soils having excess soluble salts are called saline soils and those having excess of exchangeable sodium are called alkaline or sodic soils.

- Saline and sodic soils limit the ability of a plant's roots to absorb water, and they also destroy the soil structure by breaking down and dispersing soil particles.

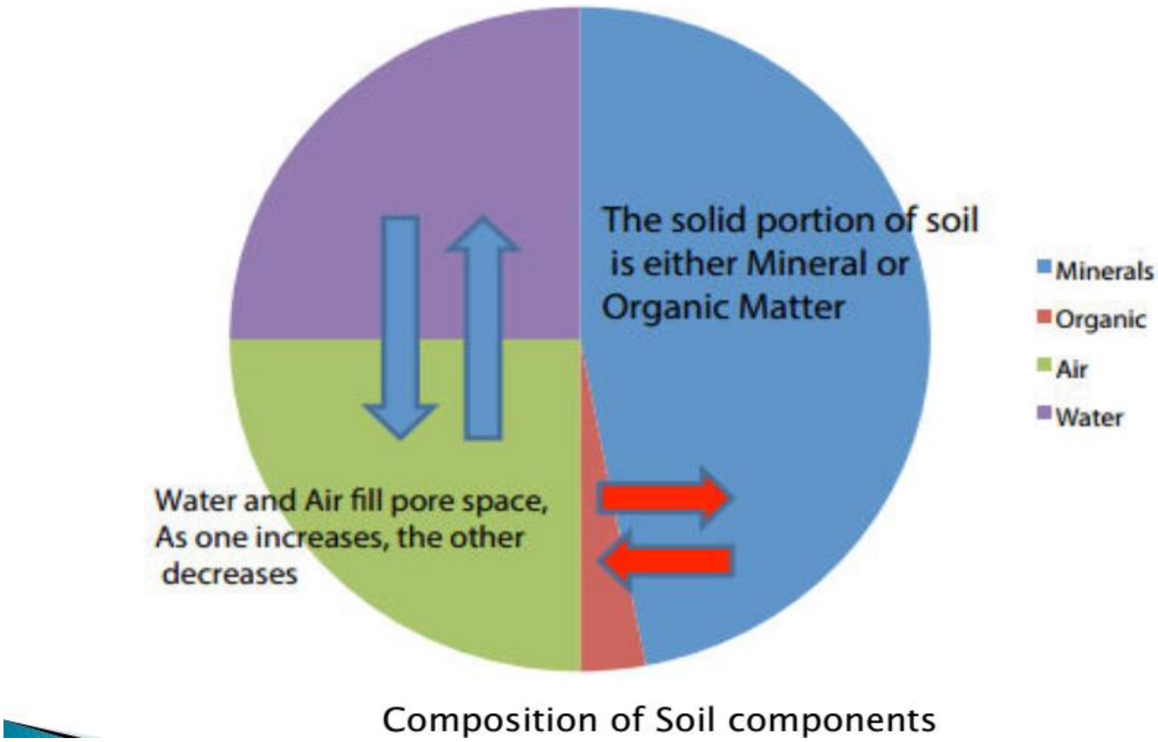
- This can negatively affect seed germination and root growth.

- Saline and sodic soils both have high pH levels, with problems typically occurring at a pH of 7.8, or extremely alkaline conditions.

- The primary difference is that saline soils also have a high salt content, while sodic soils have high sodium content.

- Soils may also have both high salt and sodium contents at the same time. When referring to saline soils, salt content describes soluble salts in the soil, which include the chlorides of sodium, calcium and magnesium, as well as carbonate salts.

- These are high enough to affect plant growth and cause plant death. When referring to sodic soils, the level of sodium in the soil dominates the other soluble salts.



Composition of Soil components

Soils - It consists of finely divided organic matter and minerals formed due to disintegration of rocks.

Classification based on geological process of formation

- Residual soil- Disintegration of natural rocks due to the action of wind, water, vegetation, frost etc.
- Alluvial soil : Deposition of eroded sediment material in the bank of rivers, streams etc.
- Aeolian soil- soils are deposited by the action of wind
- Colluvial soil- deposited at foot hills due to the action of rain water
- Volcanic soil- These are formed due to the action of volcanic eruption
- Glacial soil- These are formed due to the action of glacial erosion

Soils commonly found in India can be classified as

Alluvial soil:

- This is a largest and most important soil group. It consists of deltaic alluvium, coastal alluvium and coastal sands

Black soils:

- Typical soil derived from decan trap is black cotton soil. It is common in Maharastra, Parts of Andhra Pradesh, Mathya Pradesh, Gujarat and Tamil Nadu

Red Soil:

- It forms due to the disintegration of crystaline rocks. It is found in Tamil Nadu, Karnataka, Goa, Parts of west Bengal and Uttar Pradesh

Lateritic Soil:

- Lateritic rock composed of hydrated oxides of aluminium, iron and small amount of manganese oxide. It is found on the hills of Karnataka, Maharastra, west Bengal, Tamil Nadu, Kerala and Assam

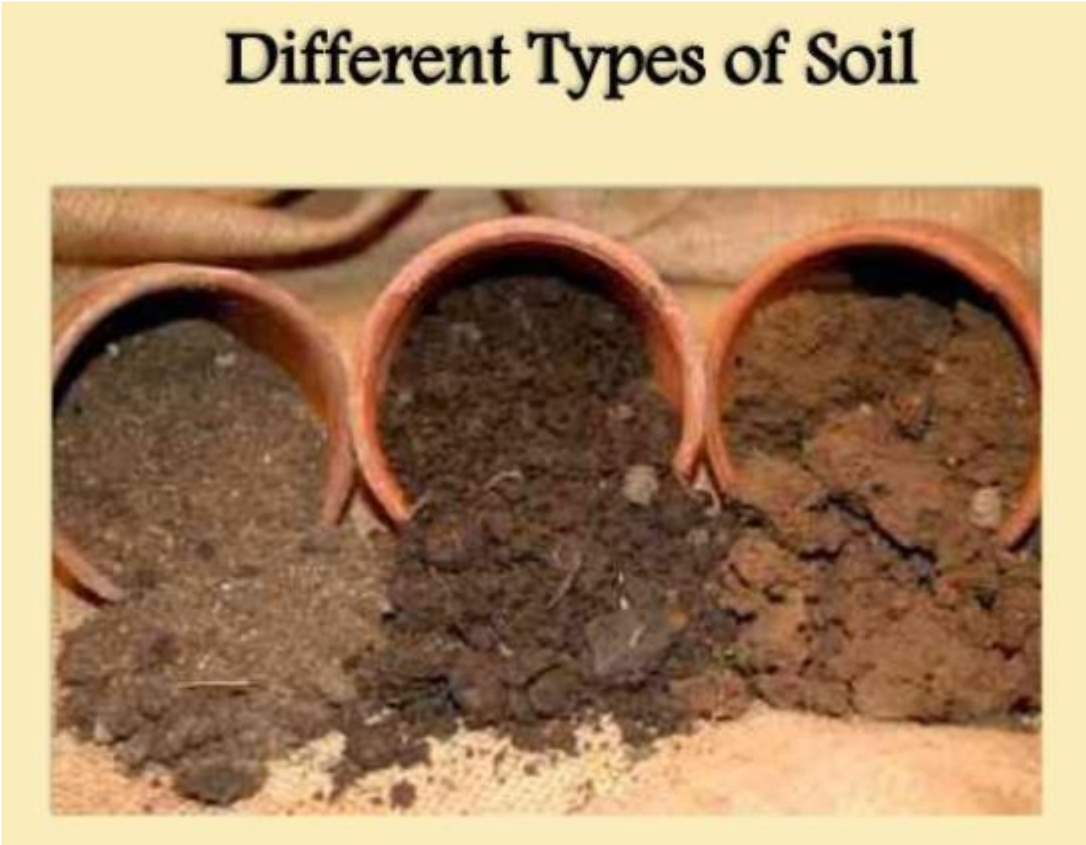
Desert Soil:

- Large part of arid region belonging to western Rajasthan, Haryana and Punjab lying between the Indus river and the aravalli range is affected by desert climate

Forest soil:

It contains high percentage of organic and vegetable matter and also called as humus.These are found in forest and foothills.

- Arable soil: Suitable for agriculture. It can be ploughed and can perform tillage
- Non Arable soil : Not suitable for agriculture



Gravitational water:

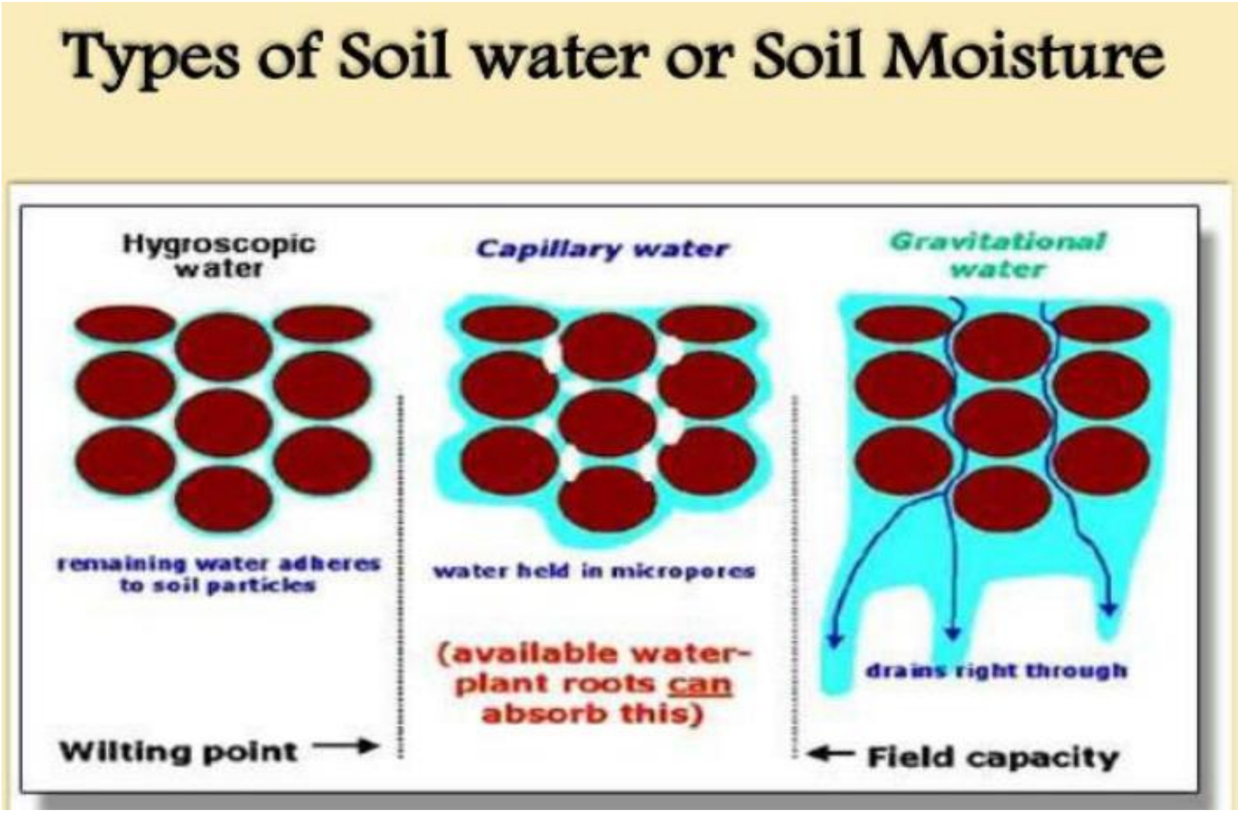
A soil sample saturated with water and left to drain the excess out by gravity. The volume of water that could easily drain off is termed as the gravitational water. This water is not available for plants use as it drains off rapidly from the root zone.

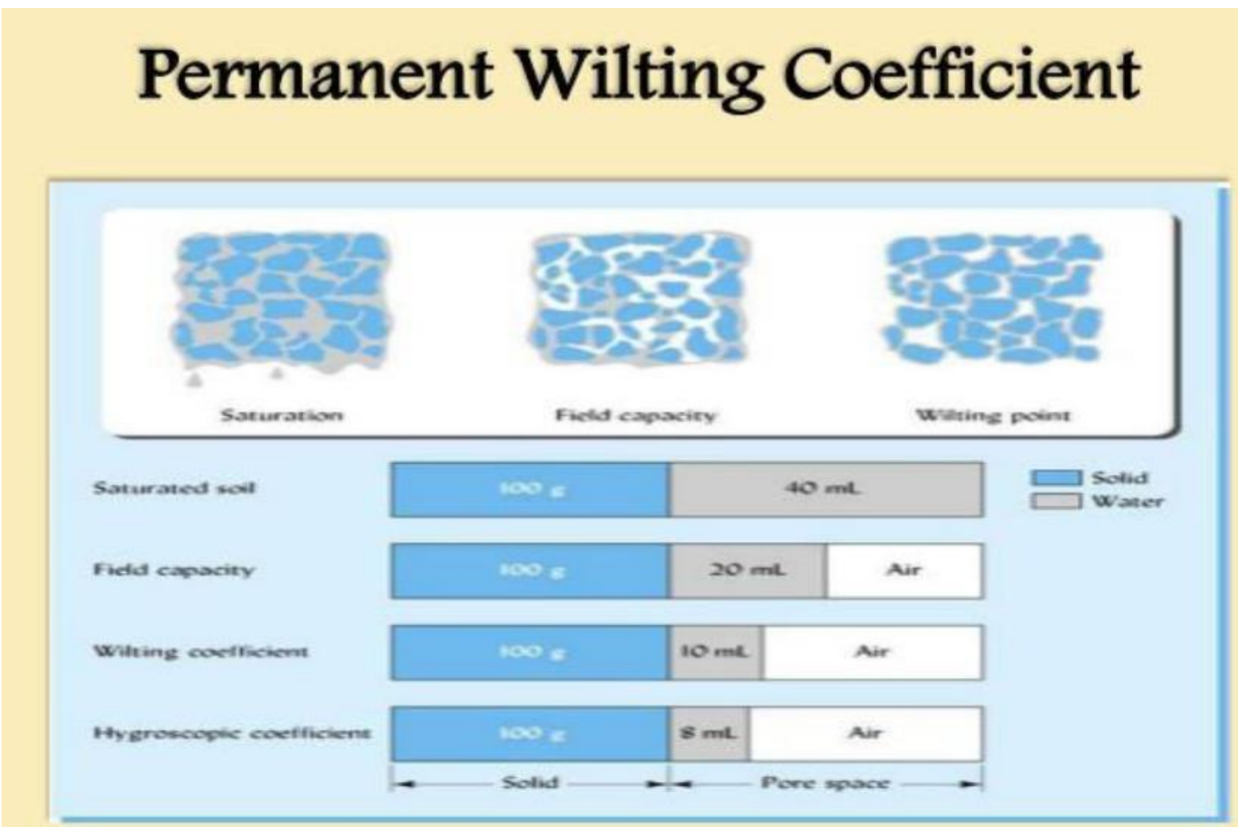
Capillary water:

The water content retained in the soil after the gravitational water has drained off from the soil is known as the capillary water. This water is held in the soil by surface tension. Plant roots gradually absorb the capillary water and thus constitute the principle source of water for plant growth.

Hygroscopic water:

It is held as a very thin film over the surface of the soil particles and is under tremendous negative pressure. This water is not available to plants.


Types of Soil water or Soil Moisture
Hygroscopic water
Capillary water
Gravitational water
remaining water adheres to soil particles
water held in micropores
(available water- plant roots can absorb this)
drains right through
Wilting point
Field capacity


Permanent Wilting Coefficient
Saturation
Field capacity
Wilting point
Saturated soil
100 g
40 mL
Solid
Water
Field capacity
100 g
20 mL
Air
Wilting coefficient
100 g
10 mL
Air
Hygroscopic coefficient
100 g
8 mL
Air
Solid
Pore space

Soil water constants

For a particular soil, certain soil water proportions are defined which dictate whether the water is available or not for plant growth. These are called the soil water constants, which are described below.

Saturation capacity:

This is the total water content of the soil when all the pores of the soil are filled with water. It is also termed as the maximum water holding capacity of the soil. At saturation capacity, the soil moisture tension is almost equal to zero.

Field capacity:

This is the water retained by an initially saturated soil against the force of gravity. Hence, as the gravitational water gets drained off from the soil, it is said to reach the field capacity. At field capacity, the macro-pores of the soil are drained off, but water is retained in the micropores. Though the soil moisture tension at field capacity varies from soil to soil, it is normally between 1/10 (for clayey soils) to 1/3 (for sandy soils) atmospheres.

Permanent wilting point:

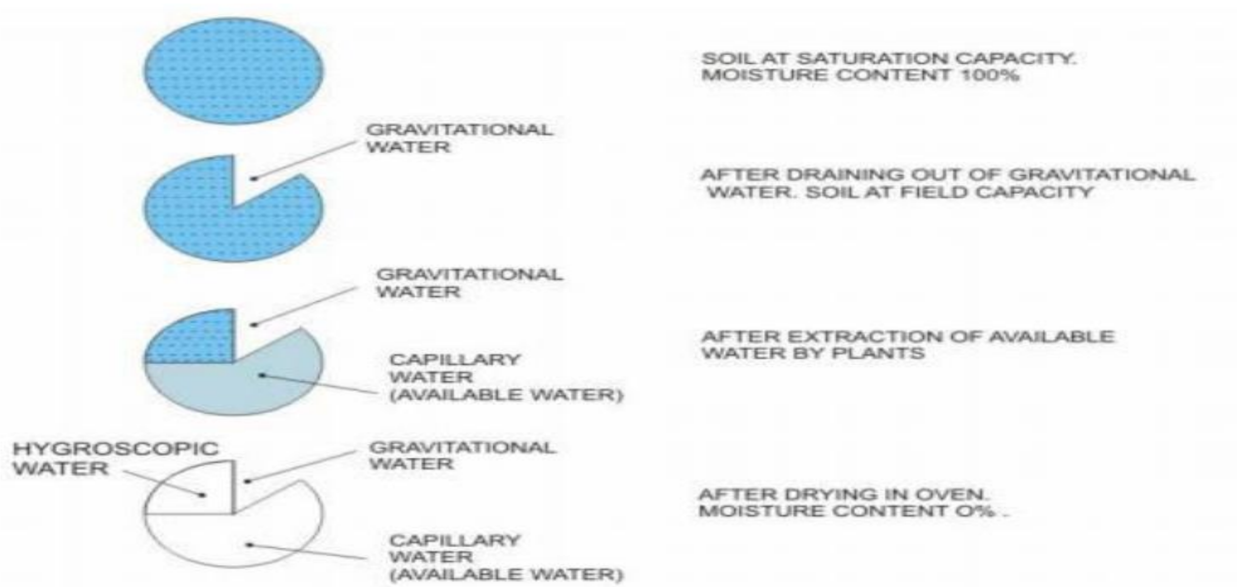
- Plant roots are able to extract water from a soil matrix, which is saturated up to field capacity. However, as the water extraction proceeds, the moisture content diminishes and the negative pressure increases.
- At one point, the plant cannot extract any further water and thus wilts.

Two stages of wilting points are recognized and they are:

- Temporary wilting point: this denotes the soil water content at which the plant wilts at day time, but recovers during night or when water is added to the soil.
- Ultimate wilting point: at such a soil water content, the plant wilts and fails to regain life even after addition of water to soil.

- It must be noted that the above water contents are expressed as percentage of water held in the soil pores, compared to a fully saturated soil.

- Figure explains graphically, the various soil constants; the full pie represents the volume of voids in soil.



Classification of soil water

- Root zone depth = D (m)
- Specific weight of soil = γs (kg/m3)
- Specific weight of water = γw (kg/m3)
- Area of plot considered = 1m x 1m

Hence, the weight of soil per unit area would be: γs x 1 x D (kg)

The weight of water held by the soil per unit area would be equal to: γ x 1 x d

Where d is equivalent depth of water that is actually distributed within the soil pores.

$$\text{Field capacity} = \frac{\text{Weight of water held by soil per unit area}}{\text{Weight of soil per unit area}}$$

$$= \frac{\gamma_w * 1 * d}{\gamma_s * 1 * D} \qquad (1)$$

Thus, depth of water (***d*** $_{Fc}$) held by soil at field capacity (***FC***)

$$= \frac{\gamma_s}{\gamma_w} * D * FC \qquad (2)$$

Similarly, depth of water (***d*** $_{wp}$) held by soil at permanent wilting point (***PWP***)

$$= \frac{\gamma_s}{\gamma_w} * D * PWP \qquad (3)$$

Hence, depth of water (***d*** $_{Aw}$) available to plants

$$= \frac{\gamma_s}{\gamma_w} * D * [FC - PWP] \qquad (4)$$

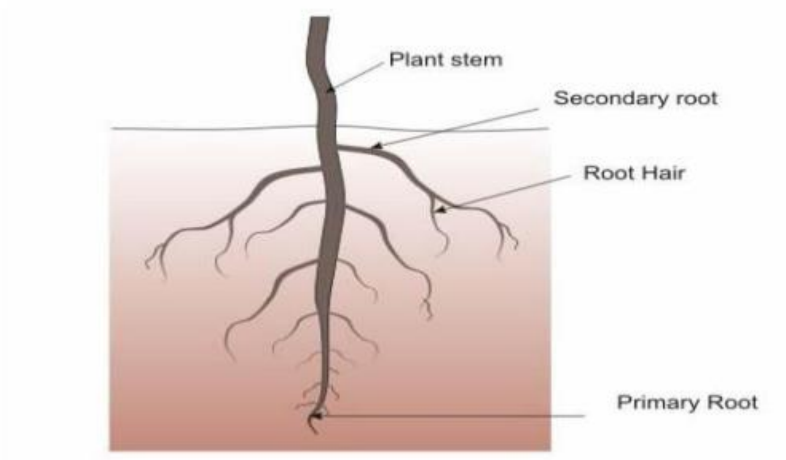
Therefore, the depth of water available to plants per meter depth of soil

$$= \frac{\gamma_s}{\gamma_w} [FC - PWP] \qquad (5)$$

Soil Texture	Field Capacity (FC) percent	Permanent Wilting Point (PWP) percent	Bulk Density(γ_s) Kg/m^3	Available water per meter depth of soil profile(m)
Sandy	5 to 10	2 to 6	1500 to 1800	0.05 to 0.1
Sandy loam	10 to 18	4 to 10	1400 to 1600	0.09 to 0.16
Loam	18 to 25	8 to 14	1300 to 1500	0.14 to 0.22
Clay loam	24 to 32	11 to 16	1300 to 1400	0.17 to 0.29
Clay	32 to 40	15 to 22	1200 to 1400	0.20 to 0.21

Water absorption by plants

Water is absorbed mostly through the roots of plants, though an insignificant absorption is also done through the leaves. Plants normally have a higher concentration of roots close to the soil surface and the density decreases with depth



Typical root density variation of a plant with depth.

- In a normal soil with good aeration, a greater portion of the roots of most plants remain within 0.45m to 0.60m of surface soil layers and most of the water needs of plants are met from this zone.
- As the available water from this zone decreases, plants extract more water from lower depths.
- When the water content of the upper soil layers reach wilting point, all the water needs of plants are met from lower layers.
- It may be noted that the water extracted from the soil by the roots of a plant moves upwards and essentially is lost to the atmosphere as water vapours mainly through the leaves.
- This process, called transpiration, results in losing almost 95percent of water sucked up.
- Only about 5percent of water pumped up by the root system is used by the plant for metabolic purpose and increasing the plant body weight.

Watering interval for crops

- A plot of land growing a crop has to be applied with water from time to time for its healthy growth.
- The water may come naturally from rainfall or may supplemented by artificially applying water through irrigation.
- A crop should be irrigated before it receives a set back in its growth and development.
- Hence the interval between two irrigations depends primarily on the rate of soil moisture depletion.
- The intervals are shorter during summer than in winter. Similarly, the intervals are shorter for sandy soils than heavy soils.

The optimum rates of soil moisture for a few typical crops are given below (Reference: Majumdar, D K, 2000)

- Maize : Field capacity to 60 percent of availability
- Wheat : Field capacity to 50 percent of availability
- Sugarcane: Field capacity to 50 percent of availability
- Barley : Field capacity to 40 percent of availability
- Cotton : Field capacity to 20 percent of availability

- As for rice, the water requirement is slightly different than the rest.
- This is because it requires a constant standing depth of water of about 5cm throughout its growing period.
- This means that there is a constant percolation of water during this time and it has estimated that about 50 to 70 percent of water applied to the crop is lost in this way.
- For most of the crops, except rice, the amount of water applied after each interval should be such that the moisture content of the soil is raised to its field capacity.
- The soil moisture depletes gradually due to the water lost through evaporation from the soil surface and due to the absorption of water from the plant roots, called transpiration

Quality of Irrigation water

- Irrigation water, regardless of its source, always contains some soluble salts in it.

- Apart from the total concentration of the dissolved salts, the concentration of some of the individual salts, and especially those which are most harmful to crops, is important in determining the suitability of water for irrigation.

- The constituents usually determined by analyzing irrigation water are the electrical conductivity for the total dissolved salts, soluble sodium percentage, sodium absorption ratio, boron content, PH, cations such as calcium, magnesium, sodium, potassium and anions such as carbonates, bicarbonates, sulphates, chlorides and nitrates.

- The quality of ground water resources, that is, from shallow or deep wells, is generally poor under the situations of

- High aridity
- High water table and water logged conditions
- In the vicinity of sea water

on the basis of suitability of water for irrigation, the water may be classified under three categories, which are shown in the following table:

Class	Electrical Conductivity (micro-ohm/cm)	Total Dissolved Solids (ppm)	Exchangeable sodium (percentage)	Chloride (ppm)	Sulphates (ppm)	Boron (ppm)	Remarks
I	0-1000	0-700	0-60	0-142	0-192	0-0.5	Excellent to good for irrigation
II	1000-3000	700-2000	60-75	142-355	192-480	0.5-2.0	Good to injurious; suitable only with permeable soils and moderate leaching. Harmful to more sensitive crops.
III	>3000	>2000	>75	>355	>480	>2.0	Unfit for irrigation