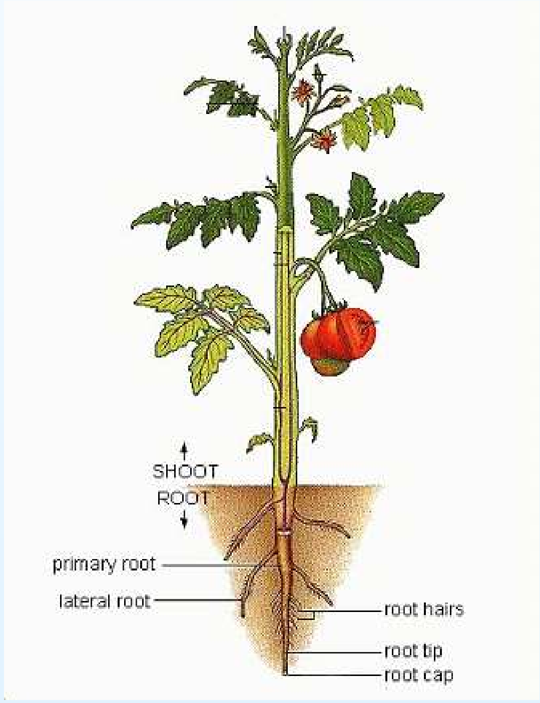
Soil Water

Introduction

The basic objective of irrigation is to ensure adequate supply of water in the root zone of plants for optimum yield of crops, without damaging the quality of the soil. This necessitates a clear understanding of the interaction among the soil, water and plants.

Root zones of most of the crops extend within 1m to 2m below the ground surface. Hence, this layer of soil is of interest to the irrigation engineer. Apart from providing the moisture needed for plants growth, the layer of the soil within the root zone provides a structural base to the plants and allows the roots to get firmly embedded in the soil. It also provides the necessary nutrients to the plants.



As such, from irrigation point of view, the soil-water-plant relationships which are of special significance include

- water retaining capacity of soil
- consumptive use of water by the plant
- movement of excess water through the soil

Since soil is capable of retaining small amount of water and part of it is lost due to evaporation and transpiration, it needs to replenished by irrigation in regular intervals.

Soil Groups

Indian soils may be divided into four major groups

- **Alluvial soils**: Soils formed by successive deposition of silt transported by ruvers during flood. These soils form the largest and most important group of soil in India. These occur in Indo-Gangetic plains and Brahmaputra plains.These soils vary from clayey yo sandy loam. Water retaining capacity is fairly good and give good response to irrigation.

- **Black soils**: Soils evolved from weathering of rocks like basalts, traps, granites and gneisses. These occur mainly in Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Maharashtra and Karnataka. These are heavy textured clayey soil with clay content more than 40%. Water holding capacity is high, but drainage is poor.

- **Red soils**: Soils formed by weathering of igneous and metamorphic rocks comprising gneisses and schists. Mostly occur in Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Maharashtra, Karnataka and Orissa. Also in some parts of West Bengal, Bihar and Uttar Pradesh. These soils are general loams and have high water holding capacity.

- **Laterite** soil: Soils derived from weathering od laterite rocks. These soils occur mostly in Karnataka, Kerala, Madhya Pradesh, Orissa, Maharashtra, Malabar and Assa. These soils have low clay content and thus have good drainage capabilities.

Classificaion of Soil-water

The water added to a soil mass during irrigation or otherwise is held in the pores of the soilwhich is termed as soil water or soil moisture. The soil water may exist in the soil in various forms

- Gravitational water
- Capillary water
- Hygroscopic water

Soil Water Storage

Soil Water Storage

Within the soil system, the storage of water is influenced by several different forces. The strongest force is the molecular force of elements and compounds found on the surface of soil minerals. The water retained by this force is called **hygroscopic** water and it consists of the water held within 0.0002 millimeters of the surface of soil particles. The maximum limit of this water around a soil particle is known as the **hygroscopic coefficient**. Hygroscopic water is essentially non-mobile and can only be removed from the soil through heating.

Capillary action moves this water from areas where the hygroscopic force is low to areas where it is high. Because this water is primarily moved by capillary action, scientists commonly refer to it as **capillary water**. Plants can use most of this water by way of capillary action until the soil wilting point is reached.

Water in excess of capillary and hygroscopic water is called **gravitational water**. Gravitational water is found beyond 0.06 millimeters from the surface of soil particles and it moves freely under the effect of gravity. When gravitational water has drained away the amount of water that remains is called the soil's **field capacity**.

Soil Moisture Constants

Certain soil moisture contents are of particular significance in relationship between soil moisture and plants. These *soil moisture contents* are often called *soil moisture constants.*

- **Field Capacity (FC)**: It is defined as the maximum amount of moisture that can be held by a soil against gravity.The field capacity is usually expressed qs the weight of the maxumum amount of water held by the soil against gravity per unit weght of the soil, and expressed as a percentage. In coarse sandy soils, the field capacity usually be achieved in about 1 to 3 days, after the soil has thoroughly wetted by irrigation. In sandy silt and sandy clay soils, about 4 to 8 days may be required for the soil to reach field capacity. For clayey soils, it may take longer periods to reach the field capacity.

- **Permanent Wilting Point (PWP)**: The permanent wilting point is defined as the amount of moisture content present in a soil when the plants become permanently wilted. At the permanent wilting point, films of water around the soil particles are held so tightly that the plant roots can not extract enough moisture at sufficient rate to satisfy transpiration requirements, thus resulting the wilting of the plants.

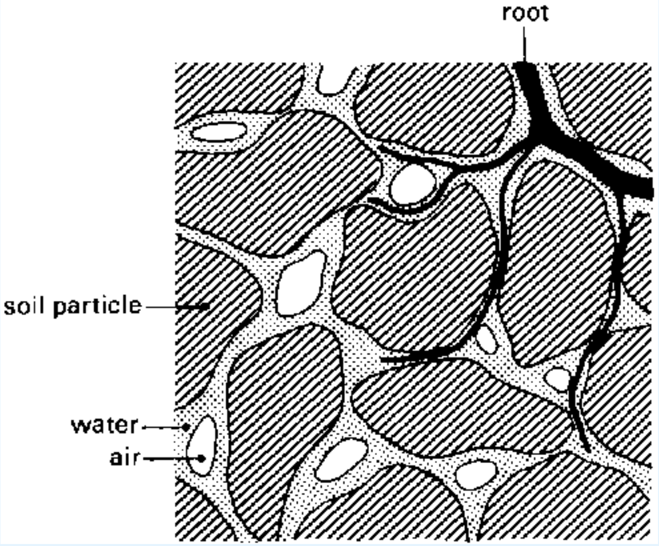
- **Available Moisture**: The difference in moisture content of the soil between the field capacity and the permanent wilting point is termed as available moisture.

- **Readily available Moisture**: It is the portion of the available moisture that is most easily extracted by the plant roots. Only about 75% of the available moisture is usually readily available.

Soil composition

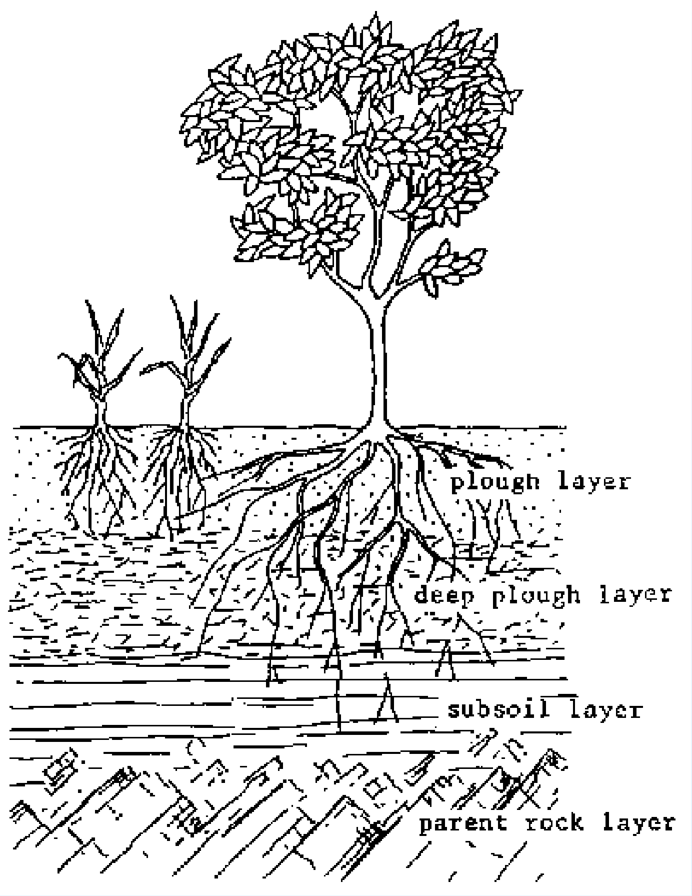
When dry soil is crushed in the hand, it can be seen that it is composed of all kinds of particles of different sizes.

Most of these particles originate from the degradation of rocks; they are called mineral particles. Some originate from residues of plants or animals (rotting leaves, pieces of bone, etc.), these are called organic particles (or organic matter). The soil particles seem to touch each other, but in reality have spaces in between. These spaces are called pores. When the soil is "dry", the pores are mainly filled with air. After irrigation or rainfall, the pores are mainly filled with water. Living material is found in the soil. It can be live roots as well as beetles, worms, larvae etc. They help to aerate the soil and thus create favourable growing conditions for the plant roots .



Soil Profile

If a pit is dug in the soil, at least 1 m deep, various layers, different in colour and composition can be seen. These layers are called horizons. This succession of horizons is called the profile of the soil.



Soil Profile

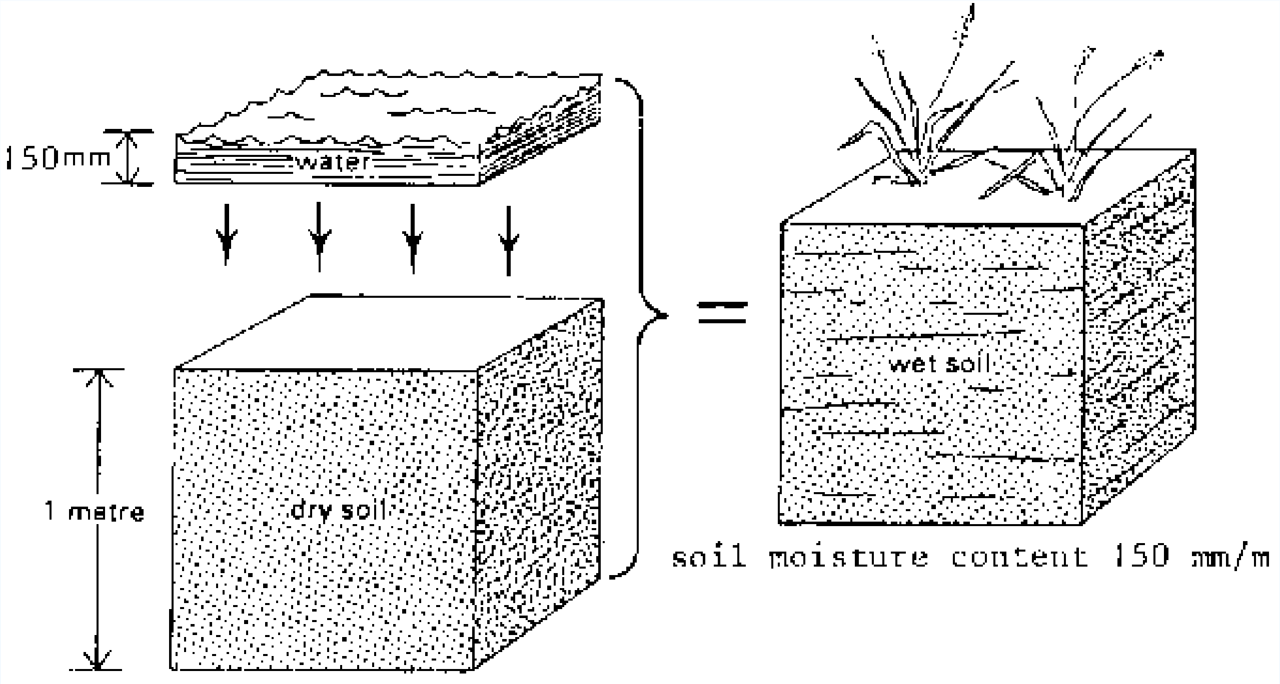
A very general and simplified soil profile can be described as follows:

- The plough layer (20 to 30 cm thick): is rich in organic matter and contains many live roots. This layer is subject to land preparation and often has a dark colour (brown to black).
- The deep plough layer: contains much less organic matter and live roots. This layer is hardly affected by normal land preparation activities. The colour is lighter, often grey, and sometimes mottled with yellowish or reddish spots.
- The subsoil layer: hardly any organic matter or live roots are to be found. This layer is not very important for plant growth as only a few roots will reach it.
- The parent rock layer: consists of rock, from the degradation of which the soil was formed. This rock is sometimes called parent material.

The depth of the different layers varies widely: some layers may be missing altogether.

Soil Moisture Content

The soil moisture content indicates the amount of water present in the soil.
It is commonly expressed as the amount of water (in mm of water depth) present in a depth of one metre of soil. For example: when an amount of water (in mm of water depth) of 150 mm is present in a depth of one metre of soil, the soil moisture content is 150 mm/m.



Soil Moisture Content

The soil moisture content can also be expressed in percent of volume. In the example above, 1 m^3 of soil (e.g. with a depth of 1 m, and a surface area of 1 m^2) contains 0.150 m^3 of water (e.g. with a depth of 150 mm = 0.150 m and a surface area of 1 m^2). This results in a soil moisture content in volume percent of:

$$\frac{0.150\,\mathrm{m}^3}{1\,\mathrm{m}^3} \times 100\% = 15\%$$

Thus, a moisture content of 100 mm/m corresponds to a moisture content of 10 volume percent.
Note: The amount of water stored in the soil is not constant with time, but may vary.

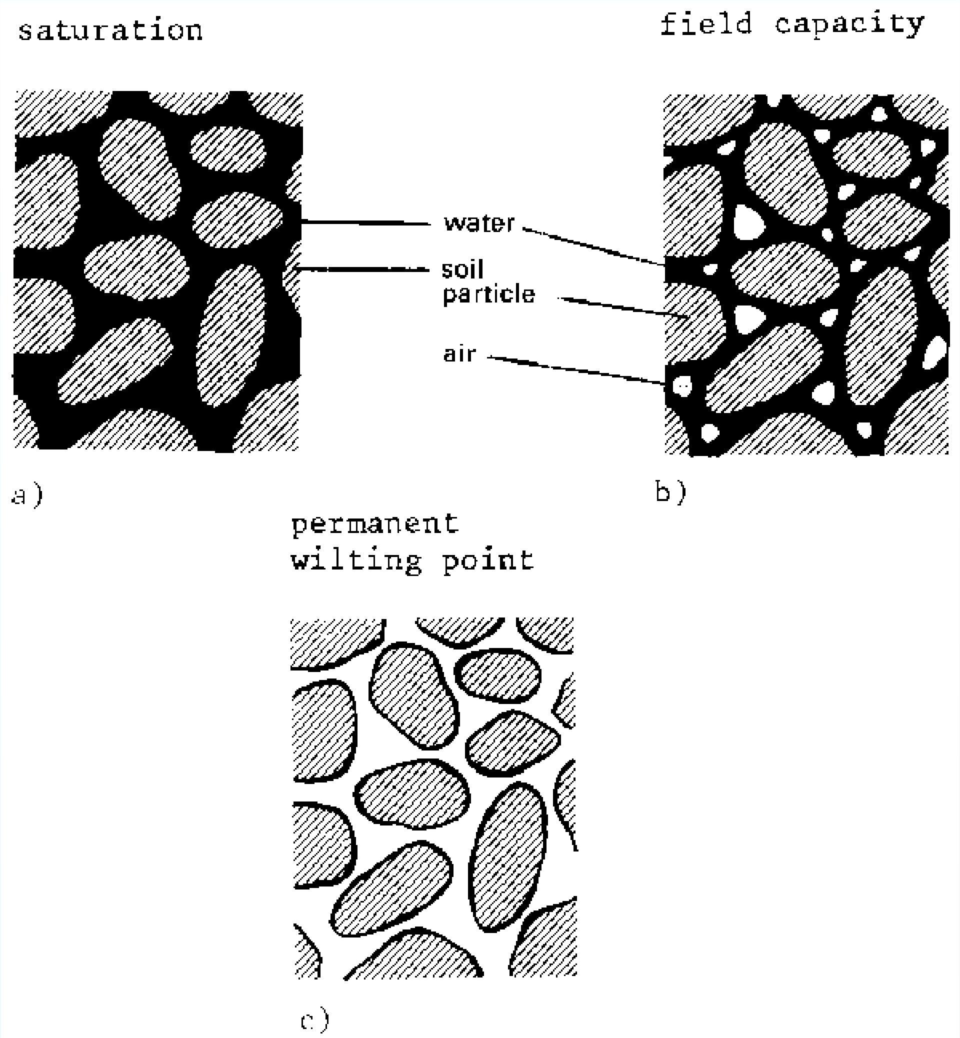
Saturation

During a rain shower or irrigation application, the soil pores will fill with water. If all soil pores are filled with water the soil is said to be saturated. There is no air left in the soil (see Fig.). It is easy to determine in the field if a soil is saturated. If a handful of saturated soil is squeezed, some (muddy) water will run between the fingers.

Plants need air and water in the soil. At saturation, no air is present and the plant will suffer. Many crops cannot withstand saturated soil conditions for a period of more than 2-5 days. Rice is one of the exceptions to this rule. The period of saturation of the topsoil usually does not last long. After the rain or the irrigation has stopped, part of the water present in the larger pores will move downward. This process is called drainage or percolation.

The water drained from the pores is replaced by air. In coarse textured (sandy) soils, drainage is completed within a period of a few hours. In fine textured (clayey) soils, drainage may take some (2-3) days.

Field Capacity



Permanent Wilting Point

Field capacity

After the drainage has stopped, the large soil pores are filled with both air and water while the smaller pores are still full of water. At this stage, the soil is said to be at field capacity. At field capacity, the water and air contents of the soil are considered to be ideal for crop growth.

Permanent wilting point

Little by little, the water stored in the soil is taken up by the plant roots or evaporated from the topsoil into the atmosphere. If no additional water is supplied to the soil, it gradually dries out. The dryer the soil becomes, the more tightly the remaining water is retained and the more difficult it is for the plant roots to extract it. At a certain stage, the uptake of water is not sufficient to meet the plant's needs. The plant looses freshness and wilts; the leaves change colour from green to yellow. Finally the plant dies.

The soil water content at the stage where the plant dies, is called permanent wilting point. The soil still contains some water, but it is too difficult for the roots to suck it from the soil.

Available Water

The soil can be compared to a water reservoir for the plants. When the soil is saturated, the reservoir is full. However, some water drains rapidly below the rootzone before the plant can use it.

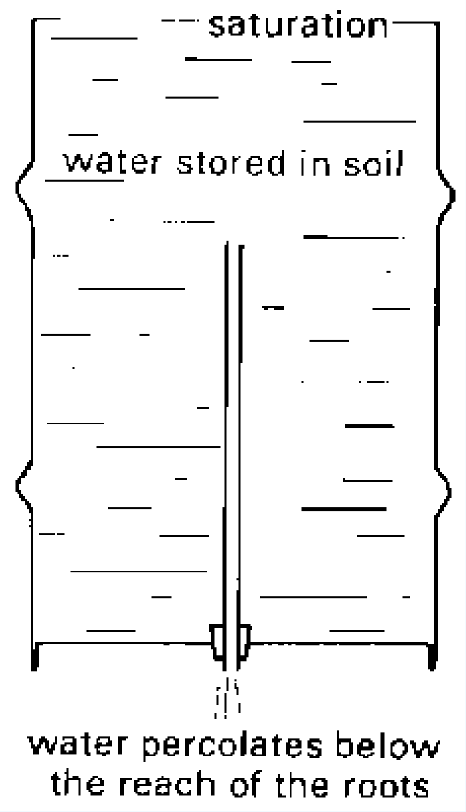


Fig. Saturation

Available Water

When this water has drained away, the soil is at field capacity. The plant roots draw water from what remains in the reservoir.

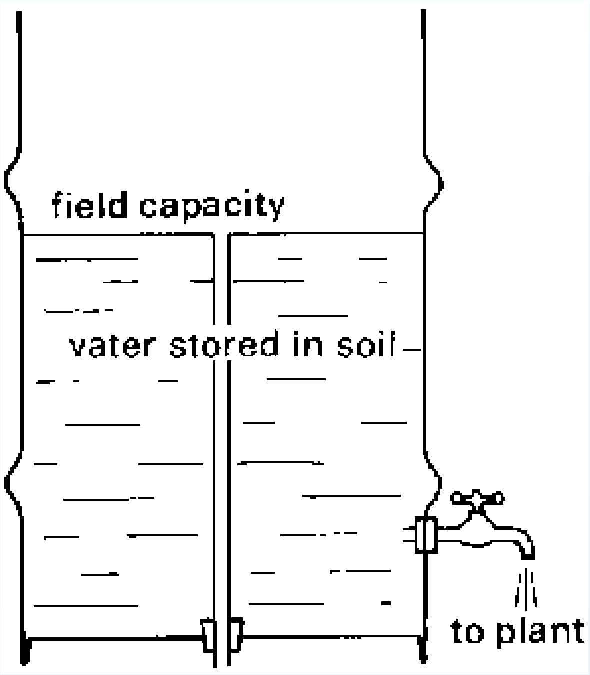


Fig. Field Capacity

Available Water

When the soil reaches permanent wilting point, the remaining water is no longer available to the plant.

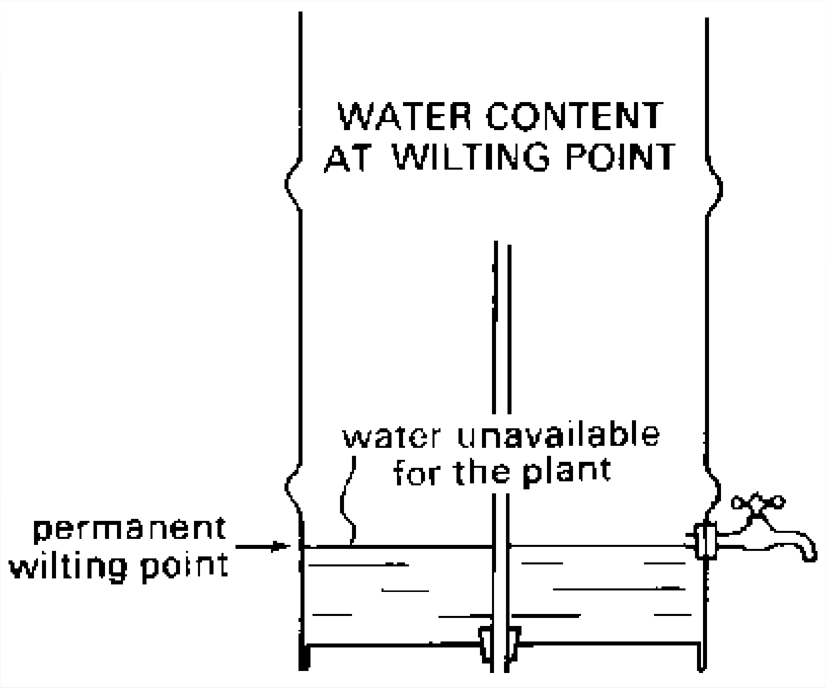
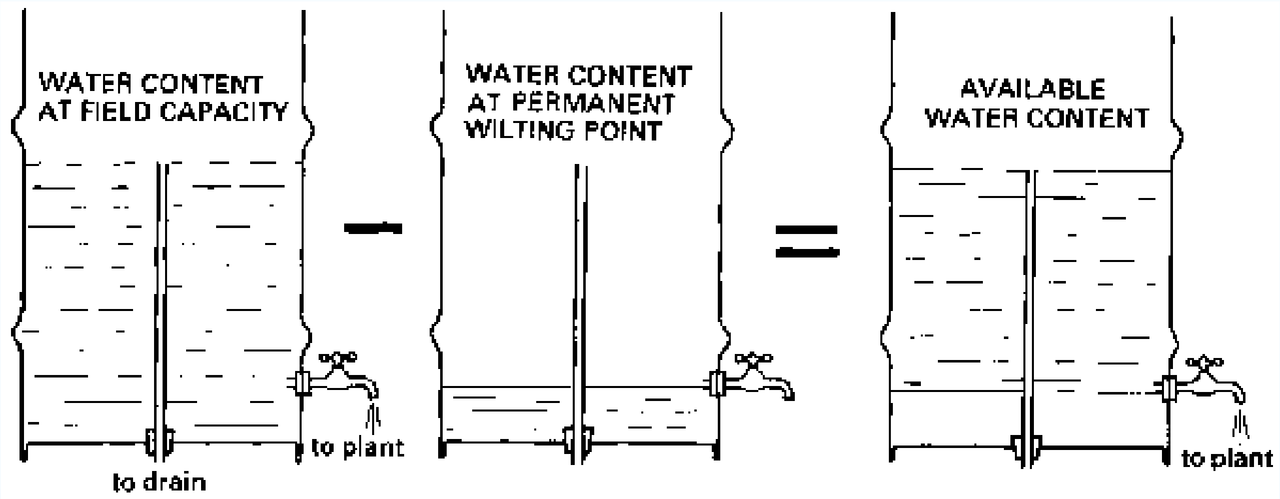


Fig. Field Capacity

Available Water

The amount of water actually available to the plant is the amount of water stored in the soil at field capacity minus the water that will remain in the soil at permanent wilting point.



Available water content = water content at field capacity - water content at permanent wilting point

Available Water

The available water content depends greatly on the soil texture and structure. A range of values for different types of soil is given in the following table.

Soil	Available Water Content (mm/m)
Sand	25 to 100
Loam	100 to 175
Clay	175 to 250

The field capacity, permanent wilting point (PWP) and available water content are called the soil moisture characteristics. They are constant for a given soil, but vary widely from one type of soil to another.

Sample Data

The average values of field capacity, permanent wilting point and available moisture (in %) for the major soil types are shown below.

Soil	**FC**	**PWP**	**Available Moisture**	**Dry Density (kg/m^3)**
Sand	5	2	3	1500
Sandy Loam	12	5	7	1400
Loam	18	10	8	1350
Silt Loam	24	15	9	1300
Clay Loam	30	19	11	1300
Clay	40	24	16	1200

Depth of Water

The moisture held by the soil in the root zone may be expressed in terms of depth of water.

Depth of water at Field Capacity

Let

d= depth of the root zone

γ_s= specific weight of the soil

γ_w= specific weight of water

d_w= depth of water in the root zone

Considering unit area of soil,

Weight of soil = $\gamma_s \times 1 \times d$

Weight of water in the root zone = $\gamma_w \times 1 \times d_w$

Now, Field Capacity, FC = weight of water held by the soil / Weight of soil =

$(\gamma_w \times 1 \times d_w)/(\gamma_s \times 1 \times d)$

Then, $d_w = (\gamma_s/\gamma_w) \times d \times FC = S \times d \times FC$

where S is the specific gravity of the soil.

Depth of Water

Depth of water at Permanent Wilting Point

$$d_w = S \times d \times PWP$$

Depth of Available Water

$$d_w = S \times d \times FC - S \times d \times PWP = S \times d \times (FC - PWP)$$

Depth of Available Water per m Depth of Soil

$$d_w = S \times (FC - PWP)$$

Depth of Readily Available Water

$$d_w = S \times (FC - RAW)$$

where RAW is the lower limit of the readily available water

Soil Water

Examples

- Example1
- Example2
- Example3
- Example4
- Example5
- Example6
- Example7

Examples

Example1

The root zone of a certain soil has a field capacity of 30% and permanent wilting point of 10%.
i) What is the depth of water in the root zone at field capacity and permanent wilting point?
ii) How much water is available, if the root zone depth is 1.2m? Take dry weight of soil as 13.73kN/m^3.

Solution:

i) The depth of moisture in the root zone at field capacity (FC)

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So, total depth of water available in the root zone

= 1.2 $\times$ 280 mm = 336mm.

Example2

Find the field capacity of a soil for the following data:

i) Depth of root zone: 2m

ii) Existing moisture content: 5%

iii) Dry density of soil: 1500 kg/m^3

iv) Water applied to soil: 600 m^3

iv) Water lost due to evaporation and deep percolation: 10%

v) Area of land irrigated: 900 m^2

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Water content before application of water was 5%.

So, field capacity = 20+5 = 25%.

Example3

A loam soil has a field capacity of 25% and permanent wilting point as 10%. The dry unit weight of soil is 14.72 kN/m^3. If the depth of root zone is 0.75m, determine the storage capacity of the soil. Irrigation water is applied when moisture content drops to 14%. If water application efficiency is 75%, determine the water depth required to be applied in the field.

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= $\frac{\gamma_s}{\gamma_w} \times$ d $\times$ [FC - PWP]

= $\frac{14.72 \times 1000}{9.807} \times 0.75 \times [0.25 - 0.1]$ = 168.8 $\simeq$ 169 mm

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= $\frac{14.72 \times 1000}{9.807} \times 0.75 \times [0.25 - 0.1]$ = 168.8 $\simeq$ 169 mm

ii) Depth of irrigation water

Example3

A loam soil has a field capacity of 25% and permanent wilting point as 10%. The dry unit weight of soil is 14.72 kN/m^3. If the depth of root zone is 0.75m, determine the storage capacity of the soil. Irrigation water is applied when moisture content drops to 14%. If water application efficiency is 75%, determine the water depth required to be applied in the field.

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= $\frac{124}{0.75}$ = 165mm.

Example4

The field capacity of a certain soil is 18.3% and its specific gravity is 1.25. A wet sample of the soil taken before irrigation weighs 153 gm and its weight after drying in the oven is 138 gm. What depth of water must be applied to irrigate the soil to a depth of 1.2m?

Example4

The field capacity of a certain soil is 18.3% and its specific gravity is 1.25. A wet sample of the soil taken before irrigation weighs 153 gm and its weight after drying in the oven is 138 gm. What depth of water must be applied to irrigate the soil to a depth of 1.2m?

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The field capacity of a soil is 12.6% and its specific gravity is 1.42. If the existing moisture content before irrigation is 8.2%, how deep the soil will be wetted when 50mm of irrigation water is applied?

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Soil Water

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= Specific gravity $\times$ depth $\times$ [difference in moisture content]

= 1.42 $\times$ d $\times$ 4.4/100

So, d = $\frac{50 \times 100}{1.42 \times 4.4}$ = 800mm

Example6

For an agricultural field producing a particular crop, available moisture holding capacity of the soil is 180 mm/m and the depth of root zone is 1.1m. Irrigation water is applied when 40% of available moisture is consumed. Total loss during irrigation is 35% and daily moisture consumption by the plant is 4.5mm. Determine frequency of surface irrigation.

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For an agricultural field producing a particular crop, available moisture holding capacity of the soil is 180 mm/m and the depth of root zone is 1.1m. Irrigation water is applied when 40% of available moisture is consumed. Total loss during irrigation is 35% and daily moisture consumption by the plant is 4.5mm. Determine frequency of surface irrigation.

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Irrigation starts when 40% of it is consumed by plants. So, depth of water replenished by irrigation = $\frac{40}{100} \times 180 \times 1.1$ mm =

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Example7

Determine the net depth of irrigation required to irrigate a field 1000m long and 10m wide, from a source supplying water at a rate of 30,000 litres per hour in clay loam soil, in moderate climate. Field capacity and permanent wilting point of the soil are 37% and 10%, depth of root zone is 1m and specific gravity of the soil is 1.35. Irrigation starts when 50% of available moisture is consumed by the plants. Also determine the time required to irrigate the field.

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Determine the net depth of irrigation required to irrigate a field 1000m long and 10m wide, from a source supplying water at a rate of 30,000 litres per hour in clay loam soil, in moderate climate. Field capacity and permanent wilting point of the soil are 37% and 10%, depth of root zone is 1m and specific gravity of the soil is 1.35. Irrigation starts when 50% of available moisture is consumed by the plants. Also determine the time required to irrigate the field.

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= 1.35 $\times$ 1 $\times$ $\frac{50}{10}$[0.37 - 0.1] m = 0.182 m = 182 mm

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Time required to supply this volume @ 30,000 litres/h

= $\frac{0.182\times10^4}{30000\times10^{-3}}$ h = 60.67 h