movement of soil water

Movement of soil water- Infiltration, percolation, permeability

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

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 with in 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.

2 **methods of estimation of water requirement and factors affecting it**

Methods of estimating crop water requirement depens on the desired level of accuracy, availability of equipment and technical know how.Some of the methods for determining crop water requirement are

1) Transpiration ratio method
2) Depth-interval-yield approach
3) Soil moisture depletion studies
4) Field experimentation
5) Climatological approaches
6) Drum culture technique for lowland rice

The crop water requirement varies from place to place, from crop to crop and depends on agro-ecological variation and crop characters. The following features which mainly influence the crop water requirement

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are:

1) Crop factors

a) Variety

b) Growth stages

c) Duration

d) Plant population

e) Crop growing season

2) Soil factors

a) Structure

b) Texture

c) Depth

d) Topography

e) Soil chemical composition

3) Climatic factors

a) Temperature

b) Sunshine hours

c) Relative humidity

d) Wind velocity

e) Rainfall

4) Agronomic management factors a) Irrigation methods used

b) Frequency of irrigation and its efficiency

c) Tillage and other cultural operations like weeding, mulching etc / intercropping etc

3	**role of water in plant**

Plants and any form of living organisms cannot live without water, since water is the most important constituent about 80 to 90% of most plant cell.

Role of water in crop and crop production can be grouped as

A) Physiological importance

- The plant system itself contains about 90% of water
- Amount of water varies in different parts of plant as follows
- Apical portion of root and shoot >90%

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- Stem, leaves and fruits - 70 - 90%
- Woods - 50 - 60%
- Matured parts - 15 - 20%
- Freshly harvested grains - 15 - 20%
- It acts as base material for all metabolic activities. All metabolic or biochemical reactions in plant system need water.
- It plays an important role in respiration and transpiration
- It plays an important role in photosynthesis
- It activates germination and plays in important role in plant metabolism for vegetative and reproductive growth
- It serves as a solvent in soil for plant nutrients
- It also acts as a carrier of plant nutrients from soil to plant system
- It maintains plant temperature through transpiration
- It helps to keep the plant erect by maintaining plant's turgidity
- It helps to transport metabolites from source to sink

B) Ecological Importance

- It helps to maintain soil temperature• It helps to maintain salt balance
- It reduces salinity and alkalinity
- It influences weed growth
- It influences atmospheric weather
- It helps the beneficial microbes
- It influences the pest and diseases
- It supports human and animal life
- It helps for land preparation like ploughing, puddling, etc.,
- It helps to increase the efficiency of cultural operations like weeding, fertilizer application etc., by providing optimum condition.

4 **soil moisture constants**

Soil Moisture Constants: The water contents expressed under certain standard conditions are commonly referred to as soil moisture constants. They are used as reference points for practical irrigation water management. The usage of these constants together with the energy status of soil water gives useful knowledge. These constants are briefly explained below:

1. **Saturation capacity**

Saturation capacity refers to the condition of soil at which all the macro and micro pores are filled with water and the soil is at maximum water retention capacity". The matric suction at this condition is essentially zero as the water is in equilibrium with free water. Excess water above saturation capacity of

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soil is lost from root zone as gravitational water.

2. Field capacity

According to Veihmeyer and Hendrickson (1950) the field capacity is "the amount of water held in soil after excess water has been drained away and the rate of downward movement has materially decreased, which usually takes place within 1 – 3 days after a rain or irrigation in pervious soils having uniform texture and structure (Fig. 9.1). At field capacity, the soil moisture tension depending on the soil texture ranges from 0.10 to 0.33 bars (or −10 to −33 kPa). Field capacity is considered as the upper limit of available soil moisture. The field capacity is greatly influenced by the size of the soil particles (soil texture), finer the soil particles higher the water retention due to very large surface area and vice versa. Thus, at field capacity, a m3 of a typical sandy soil will hold about 135 liters of water, a loamy soil about 270 liters and a clay soil about 400 liters.

3. Permanent wilting point

It is the condition of the soil wherein water is held so tightly by the soil particles that the plant roots can no longer obtain enough water at a sufficiently rapid rate to satisfy the transpiration needs to prevent the leaves from wilting. When this condition is reached the soil is said to be in a state of permanent wilting point, at which nearly all the plants growing on such soil show wilting symptoms and do not revive in a dark humid chamber unless water is supplied from an external source (Fig. 9.1). The soil moisture tension at permanent wilting point is about 15 bars (or −1500 kPa) equal to a suction or negative pressure of a water column 1.584 x 104 cm (pF = 4.2). Permanent wilting point is considered as lower limit of available soil moisture. Under field conditions PWP is determined by growing indicator plants such as sunflower in small containers. In the laboratory pressure membrane apparatus can be used to determine the moisture content at 15 bars.

4. Available soil moisture

It has been a convention and even now it is a customary to consider "the amount of soil moisture held between the two cardinal points viz., field capacity (0.33 bars) and permanent wilting point (15 bars) as available soil moisture".

Though considerable soil moisture is present below the permanent wilting point, it is held so tightly by the soil particles that the plant roots are unable to extract it rapidly enough to prevent wilting. Thus, practically it is not useful for the plants and forms the lower limit of available soil moisture. Similarly, the water above the field capacity is not available to the plants owing to quick drainage. The available soil moisture is expressed as depth of water per unit of soil and is calculated according the following formula:

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$$Available\ Soil\ Moisture\ (mm/depth\ of\ soil) = \frac{(FC - PWP)\ x\ \rho b\ x\ ds}{10}$$

Where,

FC = *Field capacity moisture (%)on oven dry weight basis*

PWP = *Permanent wilting point moisture (%)on oven dry weight basis*

ρb = *soil bulk density* (g/cm^3)

ds = *Depth of soil (cm)*

ASM = *Available soil moisture (mm/m depth of soil)*

5. Hygroscopic coefficient

It is defined as the amount of water that the soil contains when it is in equilibrium with air at standard atmosphere i.e., 98% relative humidity and at room temperature. In other words it is the amount of moisture absorbed by a dry soil when placed in contact with an atmosphere saturated with water vapour (100% relative humidity) at any given temperature, expressed in terms of percentage on an oven dry basis. The matric suction of soil water at this moisture content is nearly about 31 bars.

5 **factors affecting consumptive use of water**

Conjunctive use refers to "management of multiple water resources in a coordinated operation such that the water yield of the system over a period of time exceeds the sum of yields of the individual components of the system, resulting from in coordinated operation"

The more important of the natural influences are climate, water supply, soils, and topography. The climatic factors that particularly affect consumptive use are temperature, solar radiation, precipitation, humidity, wind movement, length of growing season, latitude, and sunlight. Data were not available for solar radiation.

1. PRECIPITATION: The amount and rate of precipitation may have some minor effect on the amount of water consumptively used during any summer. Under certain conditions, precipitation may occur as a series of frequent, light showers during the hot summer. Such showers may add little or nothing to the soil moisture for use by the plants through transpiration but do decrease the withdrawal from the stored moisture. Such precipitation may be lost largely by evaporation directly from the surface of the plant foliage and the land surface.

Part of the precipitation from heavy storms may be lost by surface runoff. Other storms may be of such intensity and amount that a large percentage of the moisture will enter the soil and become available for plant transpiration. This available soil moisture may materially reduce the amount of irrigation water needed.

2. TEMPERATURE: The rate of consumptive use of water by crops in any particular locality is probably affected more by temperature, which for long-time periods is a good measure of solar radiation, than by any other factor. Abnormally low temperatures retard plant growth and unusually high temperatures may produce dormancy. Consumptive use may vary widely even in years of equal accumulated temperatures because of deviations from the normal seasonal distribution. Transpiration is influenced not only by temperature but also by the area of leaf surface and the physiologic needs of the plant, both of which are

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related to stage of maturity.

3. HUMIDITY: Evaporation and transpiration are accelerated on days of low humidity and slowed during periods of high humidity. During periods of low relative humidity, greater rate of use of water by vegetation may be expected.

4. WIND MOVEMENT: Evaporation of water from land and plant surfaces takes place more rapidly when there is moving air than under calm air conditions. Hot, dry winds and other unusual wind conditions during the growing period will affect the amount of water consumptively used. However, there is a limit in the amount of water that can be utilized. As soon as the land surface is dry, evaporation practically stops and transpiration is limited by the ability of the plants to extract and convey the soil moisture through the plants.

5. GROWING SEASON: The growing season, which is tied rather closely to temperature, has a major effect on the seasonal use of water by plants. It is frequently considered to be the period between killing frosts, but for many annual crops, it is shorter than the frost-free period, as such crops are usually planted after frosts are past and mature before they recur.

For most perennial crops, growth starts as soon as the maximum temperature stays well above the freezing point for an extended period of days, and continues throughout the season despite later freezes. Sometimes growth persists after the first so-called killing frost in the fall. In the spring, and to less extent in the fall, daily minimum temperatures may fluctuate several degrees above and below 32° F. for several days before remaining generally above or below the freezing point. The hardier crops survive these fluctuations and continue unharmed during a few hours of subfreezing temperature. In fact, many hardy crops, especially grasses, may mature even though growing season temperatures repeatedly drop below freezing. In southern Arizona and California alfalfa and citrus trees grow throughout the year.

Although the frost-free season may be used as a guide for computing consumptive use, actual dates of planting and harvesting of the crops and average annual dates of the first and last irrigation are important in determining the consumptive irrigation requirements of the crops.

6. LATITUDE AND SUNLIGHT

Although latitude may hardly be called a climatic factor, it does have considerable influence on the rate of consumptive use of water by various plants. Because of the earth's movement and axial inclination, the hours of daylight during the summer are much greater in the northern latitudes than at the Equator. Since the sun is the source of all energy used in crop growth and evaporation of water, this longer day may allow plant transpiration to continue for a longer period each day and to produce an effect similar to that of lengthening the growing season.

7. AVAILABLE IRRIGATION WATER SUPPLY

All the above-mentioned climatic factors influence the amount of water that potentially can be consumed in a given area. However, there are other factors that also cause important differences in the consumptive use-rates. Naturally, unless water is available from some source (precipitation, natural ground water, or irrigation), there can be no consumptive use. In those areas of the arid and semiarid West where the major source is irrigation, both the quantity and seasonal distribution of the available supply will affect consumptive use. Where water is plentiful and cheap, there is a tendency for farmers to overirrigate. If the soil surface is frequently wet and the resulting evaporation is high, the combined evaporation and transpiration or consumptive use may likewise increase. Also, under more optimum soil moisture

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conditions, yields of crops such as alfalfa may be higher than average and more water consumed. In irrigating some crops, such as potatoes, water is applied to the field not only for the purpose of supplying the consumptive water needs of the crop but also to help maintain a favorable microclimatic condition.

8. QUALITY OF WATER: Some investigations have shown that the quality of the water supply may have an appreciable effect on consumptive use. Whether or not plants actually transpire more or less if water is highly saline may be debatable. However, if it is necessary to apply additional water to the land to leach the salts down through the soil, more water will probably be lost by evaporation from the soil surface and such loss will be chargeable against the consumptive requirement of the cropped area.

9. SOIL FERTILITY: If a soil is made more fertile through the application of manure or by some other means, the yields may be expected to increase with an accompanying small increase in use of water. However, an increase in fertility of the soil causes a decrease in the amount of water consumed per unit of crop yield.

10. PLANT PESTS AND DISEASES

Where plant pests and diseases seriously affect the natural growth of the plants, it is reasonable to assume that transpiration will likewise decrease. It is recognized that some damage to crops is caused every year by pests and diseases. Ordinarily the losses may not vary greatly from year to year, but in those years when they are unusually severe consumptive use may be lowered materially.

6 **The crop management techniques in saline soil**

Irrigation management

Proportional mixing of good quality (if available) water with saline water and then using for irrigation reduces the effect of salinity. Alternate furrow irrigation favours growth of plant than flooding. Drip,sprinkler and pitcher irrigation have been found to be more efficient than the conventional flood irrigation method since relatively lesser amount of water is used under these improved methods.

Fertilizer management

Addition of extra dose of nitrogen to the tune of 20-25% of recommended level will compensate the low availability of N in these soils. Addition of organic manures like, FYM, compost, etc helps in reducing the ill effect of salinity due to release of organic acids produced during decomposition. Green manuring (Sunhemp, Daincha, Kolingi) and or green leaf manuring also counteracts the effects of salinity.

Crop choice / Crop management

Crops are to be chosen based on the soil salinity level. The relative salt tolerance of different crops is as follows:

Relative tolerance of crops to salinity

Plant species -Threshold salinity (dS m-1)

Cotton -7.7

Tomato -2.5

Sugarbeet -7.0, Cabbage- 1.8

Sorghum- 6.8 ,Potato- 1.7

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Wheat- 6.0 ,Onion- 1.2

Soybean- 5.0, Carrot- 1.0

Groundnut- 3.2

Rice- 3.0, Citrus- 1.7

Maize- 1.7

Sugarcane- 1.7

Soil / cultural management

Planting the seed in the centre of the raised bed / ridge may affect the germination as it is the spot of greatest salt accumulation. A better salinity control can be achieved by using sloping beds with seeds planted on the sloping side just above the water line. Alternate furrow irrigation is advantageous as the salts can be displaced beyond the single seed row. Application of straw mulch had been found to curtail the evaporation from soil surface resulting in the reduced salt concentration in the root zone profile within 30 days.

7 **The water quality parameters and management of water logged soil**

1. **Total soluble salts**

Salinity of water refers to concentration of total soluble salts in it. It is the most important single criterion of irrigation water quality. The harmful effects increase with increase in total salt concentration. The concentration of soluble salts in water is indirectly measured by its electrical conductivity (ECw).

Salinity electrical conductivity

Adverse effects of saline water include salt accumulation, increase in osmotic potential, decreased water availability to plants, poor germination, patchy crop stand, stunted growth with smaller, thicker and dark green leaves, leaf necrosis & leaf drop, root death, wilting of plants, nutrient deficiency symptoms and poor crop yields.

Class	EC	Quality Characterization	Soil for which suitable
C1	< 1.5	Normal Water	All Soils
C2	1.5 to 3.0	Low Salinity	Light and Medium Soils
C3	3.0 to 5.0	Medium Salinity	Light and Medium Textured Soils for Semi tolerant crops
C4	5.0 to 10.0	Saline	Light medium textured soils for Tolerant crops
C5	> 10	High Salinity	Not Suitable

2. **Sodium Adsorption Ratio (SAR)**

SAR of water indicates the relative proportion of sodium to other cations. It indicates sodium or alkali hazard.

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$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

The ion concentration is expressed as meq per litre. Increase in SAR of water increases the exchangeable sodium percentage (ESP) of soil.

Sodium class	SAR value
S_1 - Low	< 10
S_2 - Moderate	10 - 18
S_3 - High	18 - 26
S_4 - Very high	> 26

Harmful effects of sodic water include destruction of soil structure, crust formation, poor seedling emergence, reduction in availability of N, Zn and Fe due to increased soil pH, Na toxicity and toxicity of B & Mo due to their excessive solubility.

3. **Residual sodium carbonate**

Bicarbonate is important primarly in its relation to Ca and Mg. There is a tendency for Ca to react with bicarbonates and precipitate as calcium carbonate. As Ca and Mg are lost from water, the proportion of sodium is increased leading to sodium hazard. This hazard is evaluated in terms of Residual Sodium Carbonate (RSC) as given below:

$$RSC\ (meq/litre) = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

RSC is expressed in meq per litre. Water with RSC more than 2.5 meq/L is not suitable for irrigation. Water with 1.25 to 2.5 meq/L is marginally suitable and water with less than 1.25 meq/L is safe for use. Permissible limits of boron content in irrigation for crops.

Boron (ppm)	Quality rating
< 3	Normal
3 - 4	Low
4 - 5	Medium
5 - 10	High
More than 10	Very high

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4. Leaching requirement

Leaching requirement (LR) is that fraction of total crop water requirement which must be leached down below the crop root zone depth to control salts within the tolerance level (ECe) of the crop.

$$Leaching\ Requirement\ (LR) = \frac{ECw}{5\,(ECe) - ECw}$$

Where:

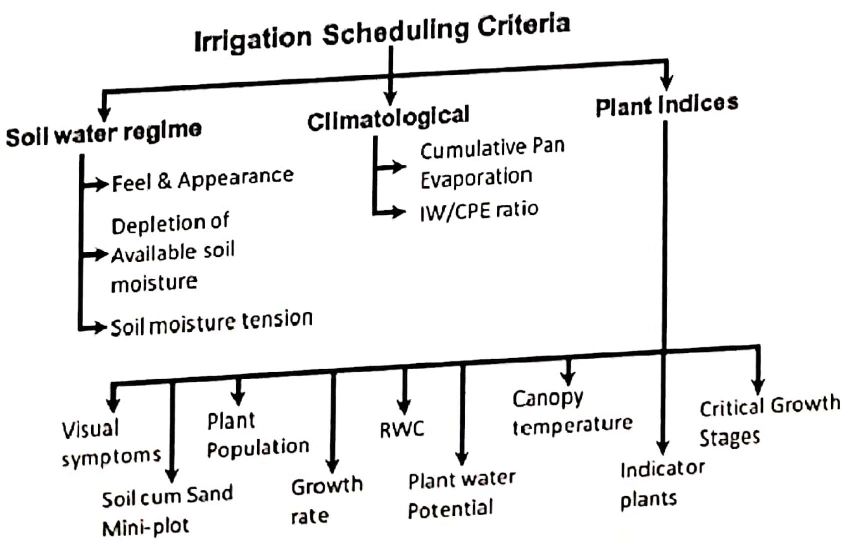
ECw = Salinity of applied water in dS/m

ECe = Threshold level soil salinity of the crop in dS/m

8 Criteria of scheduling of irrigation and Soil moisture tension

Criteria for scheduling irrigation

With the advancement of knowledge in the field of soil-plant-atmospheric system several criteria for scheduling irrigations are now available and are being used by investigators and farmers. All the available criteria can be broadly classified into the following three categories



Soil moisture tension

Soil moisture tension a physical property of film water in soil, as monitored by tensiometers (Fig.) at a specified depth in the crop root zone could also be used as an index for scheduling irrigations to field crops.

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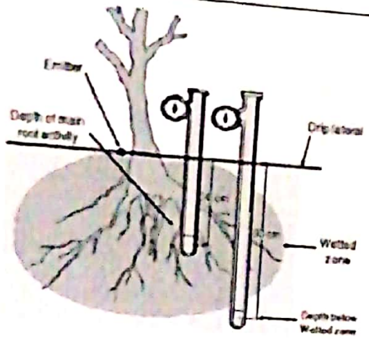
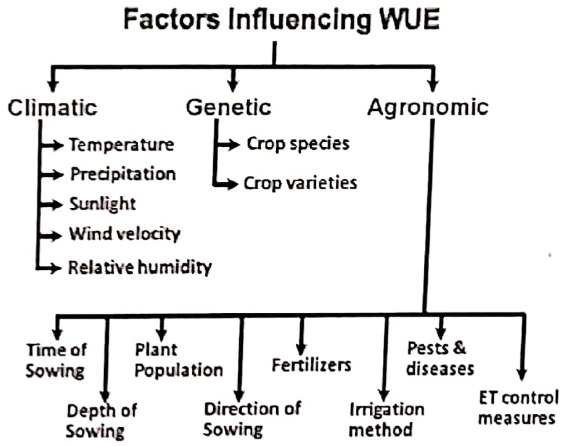


Pertinent water storage properties of soil and water use rated as affected by climatic conditions and plant vigour are intrinsically accounted for in such an irrigation schedule programme without measuring them. Tensiometers are installed in pairs, one in the maximum rooting depth and the other below this zone. Whenever critical soil moisture tension is reached say for example 0.4 or 0.6 or 0.75 bars etc in the upper tensiometer the irrigation is commenced. While the lower one (tensiometer) is used to terminate the irrigations based on the suction readings in the below soil profile zone. It is generally used for irrigating orchards and vegetables in coarse textured soils because most of the available soil moisture is held at lower tensions. Further the determination of critical soil moisture tension at which irrigation should be given has been the subject of much research

9 Factors affecting water use efficiency and crop management factors.

The factors influencing water use efficiency can be classified as follows:



Crop management factors

a) Time of sowing: Timely sowing ensures optimal temperatures, soil moisture availability and other soil physical conditions favouring optimal crop growth and development with greater ability to compete with prevalent weed flora, hence increases WUE.

b) Depth of sowing: Optimal depth of sowing affects seedling emergence, vigour and finally crop yield, hence improves WUE.

c) Direction of sowing: North south row orientation of crop rows influences the interception and utilization of incident solar radiation which in turn influences crop yield and improves WUE as

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compared to east west direction of row pattern.

d) Plant population: Optimal plant population promotes uniform & rapid development of crop canopy without any competition for growth resources viz., light, nutrients, water, CO_2 etc hence improves WUE.

e) Fertilization: Fertilization of crops suffering from low nutrition under adequate soil water availability increases crop yield considerably, with a relatively small increase in crop evapotranspiration, therefore, markedly improves WUE.

f) Insect pests & diseases: Insect pests and diseases reduce crop yield as well as WUE to varying degrees depending upon the intensity of infestation, because ETc or water requirement of crop will not change to a significant level except in cases where premature death of plants occurs.

g) Irrigation method: Field water use efficiency in general is higher with over head sprinkler, microsprinkler and drip methods of irrigation as compared to surface irrigation methods viz., furrow, border strip, check basin etc owing to higher crop yield and lower seasonal water application.

h) ET control measures: Use of mulches, anti-transpirants, shelterbelts and elimination of weeds etc reduce water losses from cropped field in terms of soil evaporation and transpiration without any reduction in crop yield, hence markedly improve WUE.

10 **Moisture extraction pattern**

The moisture extraction pattern refers to the amount of soil moisture expressed as percentage extracted from different layers in the soil profile. In most plants, the concentration of absorbing roots is greatest in the upper part of the root zone (usually in the top 45cm) and near the base of the plant. Hence extraction of water from the topsoil layers is usually more as compared to lower layers. Since water also evaporates from upper few inches of soil, it is lost rapidly from the upper layers. As the amount of moisture in the upper part of root zone in the vicinity of roots is diminished, soil moisture tension increases and a moisture suction gradient is created between the upper layers and the far away lower layer from where moisture has not been extracted previously. This causes water to move towards the upper layers to attain equilibrium between two zones, thus, the plants get moisture from lower parts of the root zone.

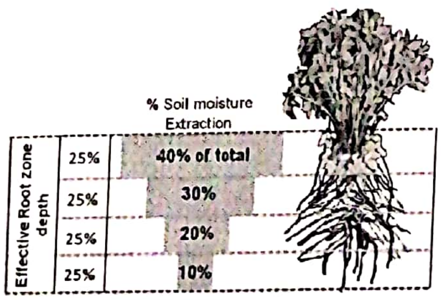

Fig.11.2. Basic soil moisture extraction curve

In uniform soils that are fully supplied with available soil moisture, plants use water rapidly from the upper part of the root zone and slowly from the extreme lower part. The basic moisture extraction

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curve indicates that for all crop plants growing in a uniform soil with adequate available water supply exhibits similar moisture-extraction pattern. The usual extraction pattern (Fig. 11.2) shows that about 40% of the soil moisture extracted is contributed from upper quarter of the root zone, 30% from the second quarter, 20% from the third quarter, and 10% from the bottom quarter. Values for individual crops may vary within the range of 10%.

Any barrier in the soil that restricts root development changes the basic moisture extraction pattern for a given crop. Similarly, if the moisture level in the

upper layers of the soil drops much below field capacity, a plant's extraction pattern differs greatly from its usual pattern.

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