A Theory Notes
on

Course No. AGRO-123 (1+1)

Title: FUNDAMENTALS OF AGRONOMY-II

As per Fifth Dean committee by 2017

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Suggested Readings of Books:

Sr. No.	Author(s)	Name of Book	Publication
1	S. R. Reddy	Principles of Agronomy	Kalyani publication. Ludhiana
2	T. Yellamanda Reddy and G. H. Sankara Reddy	Principles of Agronomy	Kalyani publication, Ludhiana
3	Dilip Kumar Muzumdar	Irrigation Water Managemnt: principles and practices	Prentice hall India Learing pvt.ltd.
4	A. M. Michel	Principles and Practices of Water Management	Vikas publication house, New Delhi
5	Lenka D.	Irrigation and Drainage	Kalyani pub., Ludhiana
6	S.C. Panda	Soil Management and organic farming	Agrobios pub. Jodhpur
7	Mishra R.O. & Ahmed M.	Manual on Irrigation Agronomy	Oxford & IBH Pub., New Delhi
8	Reddy S.R.	Irrigation Agronomy	Kalyani publication, Ludhiana
9	Y. B. Morachand	Crop production and Management	Oxford & IBH Pub., New Delhi

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Lecture-1

Definition of Irrigation and Water Management, its Objectives and Role of water in plants

IRRIGATION:

Water is an important element for plant. To meet out the demand of water to the plant irrigation is essential. Irrigation can be defined as,

"Artificial application of water to the soil to escape stress of plant is called as irrigation".

"The application of water to soil to assist in the production of crops, especially during stress period".

Properties of water:

1. The chemical formula of water: H_2O
2. Latent heat of vaporization:580 calories/g at 0 ^{0}C
3. Heat of sublimation is :680 calories/g at 0 ^{0}C
4. Heat of fusion is: 80 calories/g at 0 ^{0}C
5. Highest density of water is : 4 ^{0}C
6. Water expands on freezing: 9% by volume
7. Dielectric constant of water is: -80
8. Water has highest specific heat 1 cal/g of any known substances exceipt liquid ammonia i.e. 1.03Cal/g.

Advantages/Objectives of Irrigation:

1) To add water to the soil to supply the moisture essential for plant growth.
2) To provide crop insurance against short duration droughts.
3) To cool the soil and atmosphere, thereby making more favourable environment for plant growth.
4) To reduce hazards of frost.
5) To wash out or dilute salts in the soil.
6) To reduce hazards of piping.
7) To soften tillage pans and clods.
8) To delay bud formation by evaporative cooling.
9) To increase biological activities in soil
10) To mitigate drought effect and secure crop production.

Water management:

Water management referred as the integrated process of intake, conveyance, regulation, measurement, distribution, application of irrigation water to the field at right times, quantity and method and removal of excess water from the field for the purpose of securing maximum crop production and water economy.

Importance/Functions/Role of water in crop and crop production

A) Physiological importance

- The plant system itself contains about 90% of water
- It acts as base material for all metabolic activities.
- It plays an important role in respiration and transpiration
- It plays an important role in photosynthesis
- It 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.

Adverse Effects of Excess Irrigation

1. Irrigation without appropriate drainage leads to land degradation (waterlogging and soil salinisation) leading to reduce crop productivity

2. Ground water pollution, especially with nitrates, due to seepage of water carrying nitrate from applied fertiliser to the ground water

3. Irrigation may lead to colder and damper climate conductive to out break of pests and diseases.

Lecture-2

Water Resources of India and Maharashtra and Development

Water Resources

Rain fall

South-west monsoon

- SW monsoon reach south India (in Kerala) around 1st June of every year and in the middle of July it covers whole india under grip of rainfall.
- It's also called as Grand period of rainfall in India
- It contributes around >75 % of total rainfall in India
- It withdrawal from western Rajasthan in 1st September to complete withdrawal from whole country by 15 October.

North- East monsoon

- North east monsoon is onset at about 15 October and limited mostly to southern states (AP & TN) and withdrawal almost by mid December.
- Tamil Nadu gets highest rainfall followed by Andhra Pradesh.
- It contributes about 15% of total rainfall in India.

India's water budget/water resources:

The basic source of water is rainfall or snowfall. The water resources of India are limited. The average annual rainfall is about 1194 mm. The rain spread over an area of the country (328 m. ha), amounts to 392 m. ha-m of water and it may about 400 m ha-m including snowfall.

Total geographical area	= 328 M.ha.
Average annual rainfall	= 1194 mm
In million hectare meter	= 1194 x 328 = 392 M ha m
Contribution from snowfall	= 8 M ha m
Total	= 400 m ha m.

Considering all these factors it is estimated that out of 400 m.ha. meter of annual rainfall 70 m.ha. meter is lost to atmosphere through evaporation and transpiration, about 115 m.ha. meter flows as surface run-off and remaining 215 m.ha. meter soaks or infiltrates into the soil profile.

Sr. No.	**Geographical Information**	**India (Millian ha)**	**Maharashtra (Lakh ha)**
1	Geographical area	328.7	308
2	Cultivated area	186	208 (67.53 %)
3	Net Sown Area	142 (43.1 %)	175 (72.53 %)
4	Gross cropped area	187	223 (72.35 %)
5	Gross irrigated area	75 (39.98 %)	36.68 (16.4 %)
6	Net irrigated area	48.9	29.71 (16.90 %)
7	Cropping Intensity	140 %	127.35 %

Hydrological Cycle: The circuit of water movement from the atmosphere to the earth and back to the atmosphere through various stages like precipitation, interception of runoff, infiltration, percolation, storage, evaporation and transpiration.

Classification of Irrigation Work or Projects

The irrigation projects can be classified as: (1) major, (2) medium (3) minor based on financial limits or expenditure involved in the scheme.

Major–More than Rs. 50 million - It covers cultural command area of more than 10,000 ha.

Medium–Rs. 2.5-50 million - It covers cultural command area of 2000–10,000 ha.

Minor–less than Rs. 2.5 million - It covers cultural command area of 2,000 hectares.

Chapter III

Soil-water–plant Relationship, Soil Water, Movement of soil water, Infiltration, permeability, percolation, seepage

Soil-Plant-Water relationships:

Soil-plant-water relationships relate properties of soil and plants that affect the movement, retention and use of water. Soil is the medium for the presence of water and roots. Water as such is a carrier of nutrients. Hence it is essential to understand the physical properties of soil which ultimately decide the water and plant to be housed over it.

Water movement in the soil:

Normally water will move from higher potential to lower potential area in soil profile. Generally the water movement within the soil profile takes place under three conditions.

(1) Water movement in saturated conditions - Saturated flow occurs when water is in zero or smaller tension or at free water conditions. In this situation, all or most of the pore spaces are completely filled with water and the water moves downwards due to gravitational force. This saturated flow decreases as the soil pore space size decreases *i.e.*, the saturated flow is high in coarse textured soil than fine textured soil. Generally the rate of flow of various texture soils is in the following sequence.

Sand > loam > clay

The theory of water movement in the soil is based on Darcy's law or generalized form of Darcy's law.

Darcy's law - It states that the quantity (volume) of water passing through an unit cross-section of soil is proportional to the gradient of hydraulic head or hydraulic gradient.

(2) Water Movement in Unsaturated Condition: The unsaturated soil water movement is also called as capillary movement. In this condition the macro pores are filled with air and only micro pores are filled with water which is held relatively more tightly and water is able to move very slowly. When soil moisture decreases, a part of pore spaces is occupied by soil air and the cross-sectional area for water movement is reduced and three by hydraulic conductivity becomes low. In unsaturated conditions, the conductivity is more in fine soil than coarse textured soil. Hence, the unsaturated hydraulic conductivity is the function of soil moisture content, number, size and continuity of soil pores etc. The rate of unsaturated flow in various soil texture is in the following order.

Sand < loam < clay

(3) Water vapour movement: It takes place within the soil as well as between soil and atmosphere under dry range. The vaporization under wet range is not taken into account in irrigation practices as it is in negligible range. The finer the soil pores higher is the moisture tension under which maximum water vapour occurs. In the coarse textured soil, at low tension the soil pores become free of liquid water when soil dries out. There is little moisture left for vapour transfer.

Force acting on water movement in soil:

The retentions and movement of water in soils, the uptake and translocation in plants and its loss to the atmosphere are all energy related phenomenon.

The water moves readily from high free energy to low free energy. The more strongly water is held in the soil when greater is the heat required. This is called soil water energy concept.

Different kinds of energy are involved in this, including potential and kinetic.

1. **Matric force:** it is the force due to the attraction of the soil colloids for water which markedly reduces the free energy of the adsorbed water molecules.
2. **Osmatic force:** it is the force due to the attraction of ions and other solutes for which to reduces the free energy of soil solution. Matric and osmatic potentials are negative and reduces the free energy level of the soil water.
3. **Force of gravity:** it is the force due to the attraction towards the earths centre, which leads to pull the water downward. This force is always positive.

Movement of water into the soil

The main process through which water enters into the soil is as follows, Infiltration, Permeability, Percolation, Capillary movement and Seepage.

Infiltration

The downward movement of water from the surface into the soil is called infiltration and it is expressed in cm/hour. **It occurs in unsaturated soil.**

Infiltration rate is the rate at which water is passing through the soil surface and flowing into the soil profile.

Soil type	**Infiltration rate (mm/hr)**
Sandy and silty soils	10 to 20
Loams	5 to 10
Clayey soils	1 to 5
Sodic clayey soils	<1

Factors affecting Infiltration Rate:

(1) Compactness of soil surface: A compact soil surface permits less infiltration whereas more infiltration occurs from loose soil surface.

(2) Impact of rain drop: the force (speed) with which the rain drop falls on the ground is said to be impact of rain drop. Ordinary size varies from 0.5 to 4mm in diameter. The speed of raindrop is 30ft per second and force is 14 times its own weight. When impact of raindrop is more then it causes sealing and closing of pores (capillaries) especially in easily dispensable soils resulting in infiltration rate

(3) Soil cover: Soil surface with vegetative cover has more infiltration rate than bare soil because sealing of capillary is not observed.

(4)Soil Wetness: If soil is wet, infiltration is less. In dry soil, infiltration is more.

(5)Soil temperature: Warm soil absorbs more water than cold soils.

(6)Soil texture: In coarse textured soils, infiltration rate is more as compared to heavy soils. In coarse textured soil, the numbers of macro-pores are more. In clayey soils, the cracking caused by drying also increases infiltration in the initial stages until the soil again swells and decreases infiltration.

(7) Depth of soil: Shallow soils permit less water to enter into soil than too deep soils.

Percolation: It is the vertical movement of water in the soil due to force of gravity. Percolation occurs when water is under pressure or when the tension is smaller than about 1/2 atmosphere. **It occurs in saturated soil.**

Seepage: It is the horizontal flow of water in channel or canal is called seepage. Water loss from channel or canal mainly due to seepage.

Permeability: The ability of a soil to movement of air and water is known as permeability. Soils high in clay have small pore spaces, so water passes through only slowly.

Leaching: Downward movement of nutrients and salts from root zone with the water is called leaching.

Capillarity: Capillarity refers to the energy with which water is held by soil. If a lower end of glass tube of capillary size is placed in water the liquid rises in the tube above the level of the water surface outside. This phenomena is called capillarity.

Duty of water: Volume or quantity of water required for irrigation to bring a crop to maturity.

Duty of water=8.64 x Base (Period) / Delta (Depth of water)

1 CUMEC (Cubic metre per Second) day = 8.64 hectare metre=86400 m^3

Base period

The period (days) during which irrigation water is supplied to the crop.

Delta

Delta is the total depth of water (cm) required by a crop during its duration in the field.

Chapter IV

Volume Mass Relationship, retention of soil water and factors affecting it.

Forces of water retention by soil

Water that enters into the soil is retained by means of three forces, viz., 1) Adhesion 2) Cohesion and 3) due to soil colloids like clay and humus. Water molecules do not exist individually. Hydrogen in the water serves as connecting link from one molecule to other is known as hydrogen bonding.

1) Adhesion (also called adsorption)

The water molecules get attached to the surface of the soil particles and that make a thin film of water which is tightly held around the soil particles is known as force of adhesion. Adhesion is operative only at the solid-liquid interface and hence film of water is established by it is very thin. By adhesion, water film is held more tightly at the soil-water interface.

2) Cohesion

Water sticks itself with great energy and this property is known as cohesion. Water molecules hold other water molecules by cohesive forces. This force makes thick water film due to attraction of water molecule to each other and it is operative at only liquid interface.

3) Soil colloids (Clay or humus particles)

The water is also retained in the soil colloids like clay or humus particles. These soil colloids absorb water and as result of it get swollen. The water thus retained in the soil as called imbibitional moisture.

Soil water potential

The difference between the free energy of soil water and that of pure water in standard difference state is termed soil potential. Soil water potential is due to the influence of force fields resulting from gravitational, metric, osmotic and pressure forces.

Gravitational potential

Gravitational potential is the potential attributable to the gravitational force and is dependent on the elevation. It is the amount of work that a unit quantity of water in an equilibrium soil-water (or plant-water) system at an arbitrary level is capable of doing when it moves to another equilibrium identical in all respects except that it is at a reference level.

Metric potential

The total water potential that is attributed to the solid colloidal matrix of the soil or plant. Metric potential is negative potential which results from the capillary and adsorptive forces emanating from the soil matrix.

Osmotic or solute potential

Osmotic or solute potential is the portion of water potential that results from the solutes present in the soil. They reduce free energy of water as the salts ions or molecules attract water molecules. Osmotic potential is negative.

Pressure potential is the result of hydrostatic pressure acting on soil water. An increase in pressure increase water potential and pressure potential is positive.

Chapter V

Classification of Soil Water, Soil Moisture Constants, Soil Moisture characteristic curve

Kinds/Classification of soil water/ Different forms of soil moisture:

A) Physical classification: Based on relative degree of retention,

1. Gravitational water
2. Capillary water
3. Hygroscopic water

1. Gravitational water (Drainage water)

- It is usually present in macro pores.
- It held by a negative tension of less than 0.3 atm.
- Free water which drains out.
- It is not available to plants and detrimental to plants
- It dissolves plant nutrients & these nutrients leached away.

2. Capillary water

- It is present in micropores of soil
- Held between field capacity and hygroscopic co-efficient in micropores.
- At tension of 0.3 to 31 atm.
- Function as soil solution
- It is available for plant growth.

Capillary water divided in to inner capillary and outer capillary water:

- **Inner capillary water**: It is that part of capillary water which is nearer to the hygroscopic water. It is in the form of thinner films, held more tightly and moves rather very slow than outer capillary water.
- **Outer capillary water**: It is that part of capillary water which is not very tightly held in the soil and therefore moves readily from place to place. It is the most useful water for the plants because of its very quick availability.

3. Hygroscopic water

- This water is held very tightly as thin film around soil particles by adsorption forces and therefore plant can not absorb it.
- It held at hygroscopic co-efficient.
- Tension varies from 31 to 10,000 atm.
- Moves in vapour form therefore biologically inactive.

B) Biological classification of soil water: (Basis of available to plants)

There is a certain relationship between soil moisture retention and its utilization by plants. On the basis, superfluous, available water and unavailable water are recognized.

1. Superflous water (Free water or drainable water)

It is excess of that held in soil at field capacity and has no use for higher plants. This water is held at a tension below 0.1 to 0.3 atmosphere. It is also known as free or gravitational water.

2. Available water (Available soil moisture, ASM)

Soil moisture between field capacity and permanent wilting point is referred to as readily available moisture. It is the moisture available for plant use. Held between 0.3 to 15 atm.

3. Unavailable water

It is held in the soil at the permanent wilting point (≥15 atm.) unavailable water includes hygroscopic water and that part of the capillary water held between 15 to 31 atmosphere which is utilized by plants too slowly to prevent wilting.

$$\text{Unavailable water (cm/depth)} = \frac{\text{PWP (\%)}}{100} \text{ x BD x D}$$

Soil Moisture Constants: it is the study of water and its availability

Water available in the soil at standard crop growth stage is called soil moisture constants.

1. Maximum water holding capacity (MWHC) or Saturation capacity (SC)

- When all the pores of the soil are filled with water, the soil is said to be under saturation capacity of *maximum water holding capacity*.
- The tension of water at saturation capacity is almost zero and it is equal to free water surface.

2. Moisture equivalent (ME)

- Moisture equivalent is defined as the amount of water retained by initially saturated soil after being subjected to a centrifugal force of 1000 times that of gravity for about half an hour.
- The moisture content when expressed as moisture percentage on oven dry basis, gives the value of the moisture equivalent.
- In medium textured soils, the values of field capacity and moisture equivalent are nearly equal. In sandy soils, the field capacity exceeds the moisture equivalent.
- In very clayey soils, the field capacity is generally lower than the moisture equivalent.
- It represents moisture content in the inner capillary or micro capillary pores,.

3. Field capacity (FC)

- The moisture held by soil against gravitational force is called filed capacity
- At field capacity, the large soil pores are field with air, the micro pores are filled with water and any further drainage is slow.
- The field capacity is the upper limit of water availability to plants.
- The soil moisture tension between -0.1 to -0.33 atmospheres.
- It is determined with the help of presser plate apparatus.
- The moisture content at the FC is taken as 100%.
- It comes after 48 to 72 hrs after irrigation.

4. Permanent wilting point (PWP) or wilting co-efficient

- Permanent wilting point proposed by Briggs & Shantz (1912)

- The soil moisture content at which plants can no longer obtain enough moisture to meet transpiration requirements; and remain wilted unless water is added to the soil.
- Its is the lower limit of available soil moisture to plant.
- Soil moisture tension at PWP is about 15 atmosphere or -15 bars.
- Wilting point in most soil is in the region of 50% FC.
- PWP is determined by growing dwarf sunflower plant.

5. Ultimate wilting point (UWP):

The moisture content at which wilting is complete and the plant die is called **ultimate wilting point (UWP).** At UWP the soil moisture tension is as high as -60 bars.

6. Available soil moisture (ASM): Moisture available for plant growth is the capillary water between FC & PWP. It can be determined by**, ASM=FC-PWP**

7. Hygroscopic co-efficient

- Air dried soil at atmosphere contains tightly bound water with soil particles and water if macro and micro pores are completely replaced by air. The metric section of this stage is called hygroscopic coefficient.
- The clay soil contains more colloidal materials contain more hygroscopic water than sandy soil.
- At this moisture constant, the metric potential of soil water is about 31 atmosphere.
- At this point water in the soil is adsorbed on the soil colloids so tightly that it can move only in vapour form.

Factors affecting available water/soil moisture:

Sr. No.	Factors	Description
1	Soil texture	Fine textured soils have more water holding and retention capacity, so more water availability.
2	Soil structure	Well aggregated soils have more retention of water, so have more available water.
3	Organic matter	Soils with higher organic matter have higher water holding, thus more water is available for plants
4	Soil compaction	Less compact soils have higher number of total pore space which results in high water retention.
5	Soluble salt	Presence of high soluble salts in the soil increase osmotic potential results in low available water content.
6	Soil depth	High soil depth has high available water content.

Soil moisture characteristic curve:

- ➢ A curve showing relationship between the energy status of water (tension) and amount of moisture in soil. As the energy status of soil decreases, soil water content also decreases.
- ➢ In other words, as the soil moisture content decreases, more energy has to be applied to extract moisture from the soil.

Soil moisture characteristic curve:

- o For sandy soil: L shaped
- o For clay soils: I shaped (almost a straight line)

Chapter-6

Water absorption, factors affecting absorption, rooting characteristics, Moisture extraction patterns and SPAC

Absorption of Water:

In plants, water is absorbed through root hairs, which are in contact with soil water. The wall of the root hairs are permeable and consists of pectic and cellulose substances which are strongly hydrophilic (water loving) in nature. There are two types of absorption *viz.*, (*a*) Active absorption, and (*b*) Passive absorption.

(*a*) ***Active absorption*** **–** Active transport depending on expenditure of metabolic energy mass flow move same direction in mass**.** Here the process of osmosis plays an important role. The soil plant water movement can be effected due to forces of imbibition, diffusion and osmosis.

(*b*) ***Passive absorption*** **–** Passive movement by mass flow and diffusion without spending energy. Passive absorption takes place when rate of transpiration is very high. It is otherwise known as transpiration pull.

Factors affecting absorption of water:

Water absorption by plants is influenced by environmental and plant factors. The former includes mainly the atmospheric and soil factors.

(*i*) ***Available soil water*** **-** Capillary water is available to plants. Hygroscopic water and gravitational water are not available to plants. The capillary water is absorbed by the plants, which in turn reduces the soil water potential. Hence, the water from higher potential area tends to move to lower potential area and root will absorb this water. This is the chain of process involved in water uptake.

(*ii*) ***Concentration of soil solutions*** **-** High concentration affects the process of osmosis.

(*iii*) ***Soil air*** - Sufficient amount of O2 should be there and excess amount of CO2 affects the availability of water by root suffocation.

(*iv*) ***Soil temperature*** **-** Up to 30oC favours absorption. Very low and very high temperature affects absorption.

(*v*) Soil texture

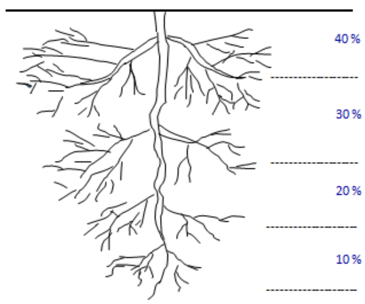
Clay – Neither good nor bad
Sand – Not good for absorption
Loamy – Good for absorption

Moisture extraction pattern with Diagram:

The moisture extraction pattern revels about how the moisture is extracted and how much quantity is extracted at different depth level in the root zone. The moisture extraction pattern shows the relative amount of moisture extracted from different depths within the crop root zone.

It is seen that about 40% of the total moisture is extracted from the first quarter of the root zone, 30% from second quarter, 20% from the third quarter and 10% from last fourth quarter. This indicates that in most of the crops the effective root zone will be available in the 1^{st} quarter.

Moisture Extraction Pattern by Roots



Rooting characteristics

The root system is extremely variable in different crop plants. The variability exists in rooting depth, root length and horizontal distribution of roots. These are further influenced by environmental factors and the genetic constitution. The roots of cereals apparently occupy more surface area of the soil then other crops. For example, it has been proved that cereals' roots extend to 200-400 cm m2 of soil surface area as against 15-200 cm m2 for most graminaceous plants.

Plants vary genetically in their rooting characteristics, Vegetable crops like onion, potato, carrot etc., have very sparse rooting system and unable to use all the soil water in the root.
Rice, Grasses, sorghum, maize, sugarcane have very fibrous dense root system which can extract much water from soil. Millets, groundnut, grams are moderately deep rooted.

Maize, sorghum, lucerne, cotton and perennial plants have deep root system and can utilize effectively the moisture stored in root zone as well as in the unexploited deeper zones. Crops which have dense and deep root system like cotton, sorghum, red gram tolerate high reduction of soil water content. Shallow rooted crops like rice, potato, tomato tolerate low level of soil water reduction. Moderately deep rooted crops like millets, groundnut, grams tolerate medium level of soil water reduction.

The root growth of the crop plants is affected by

1. Genetic nature
2. High water table
3. Shallow nature of soil and permeability of soil layer
4. Soil fertility
5. Salt status of soil

Effective root zone depth

It is depth in which active root proliferation occurs and where maximum water absorption is taking place. It is not necessary that entire root depth should be effective.

Soil-plant atmospheric continuum (SPAC):

The complete path of water from the soil through the plant to the atmosphere forms a continuous system referred as SPAC. **OR** The rooting zone of the plant in the soil, plant and the lower layer of atmosphere behave as a continuum in relation to water movement or water transfer is known as soil-plant atmospheric continuum (SPAC).

Flow path of water is complex. In SPAC, water moves from higher potential to lower potential. The water potential at field capacity is -0.01 to -0.03 mpa and at wilting point is -1.5 mpa (Mega pscal).

In this continuum, the soil water enters the root cells, from root cells, it passes to the leaves of plant through stem xylem cells, where it leaves plant body and disperses in to surrounding atmosphere.

This system may be analyzed by evaluating the potential difference between soil and atmosphere in contact with root and leaf, respectively.

The following are the main areas of water movement in plant system:

- ✓ Water absorption
- ✓ Water adsorption
- ✓ Water conduction and translocation
- ✓ Water loss on transpiration

The path of water may be divided into four sequential processes as follows:

- The supply of soil water to the root surface-adsorption,
- The entry of water in to the root-absorption,
- The passage of water in the conducting tissues- (Xylem) translocation or conduction and
- The movement of water vapour through and out of the leaves-transpiration or loss of water.

The rate of water movement is directly proportional to potential gradient *i.e.*, higher potential to lower potential and inversely proportional to the resistance to flow.

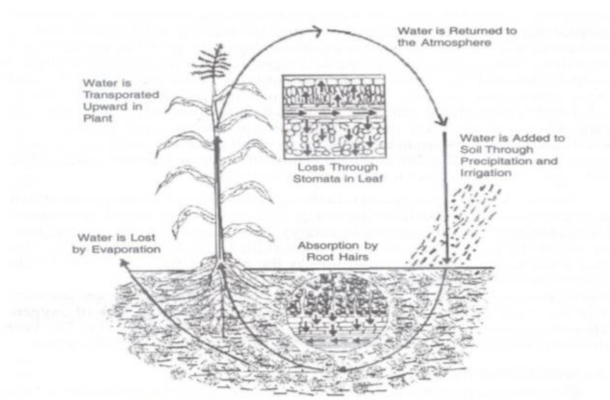


Fig. 10.3: Soil-plant-atmosphere Continuum (SPAC)

Chapter-7

Water requirement, Irrigation Requirement, Gross Irrigation, Net Irrigation, Irrigation interval and Methods of estimation of water requirement and factors affecting it

Crop water requirement (WR) implies the total amount of water required at the field head regardless of its source, to mature a crop. It includes the amount of water needed to meet the losses through evapo-transpiration, application lossess and the special needs like leaching of excess salts, puddling, pre-planting irrigation etc. The water requirement (WR) thus can be expressed as: WR = CU + Application losses + Water needed for special operation

WR= Irrigation + Effective rainfall + Ground water contribution + Change in soil moisture

Factors influence the crop water requirements are:

1) Crop factors

a) Crops and varieties: tall crops and varieties intercept more solar radiation and have more ET than short crops and varieties.
b) Growth stages
c) Duration: Longer duration, higher the water requirement.
d) Plant population
e) Crop growing season
f) Rooting habits: Deep rooted crops extract more water from deep soil layers.

2) Soil factors

a) Soil Structure
b) Soil Texture
c) Soil Depth
d) Soil Topography
e) Soil chemical composition
f) Hydralulic conductivity: Coarse textured soils have higher hydraulic conductivity than fine textured soil at high soil moisture regime.
g) Reflectivity:
h) Thermal properties

3) Climatic factors

a) Temperature
b) Sunshine hours/solar radiation
c) Relative humidity
d) Wind velocity
e) Rainfall

Higher solar radiation, temperature and wind velocity increase crop water needs. Higher humidity reduces ET. Hot and dry winds around irrigated crop increases the ET.

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

Based on al these factors, average crop water requirement for various crops have been worked out and given below for tropical conditions.

Irrigation requirement (IR):

Irrigation requirement (IR) refers to the quantity of water, exclusive of effective rainfall (ER) and contribution from soil profile (S) required for crop production. This amounts to net irrigation requirement plus other economically unavoidable lossess.

IR - WR – (ER + S)

Net irrigation requirement (NIR):

It is the amount of irrigation water just required to bring the soil moisture content in the effective crop root zone depth to field capacity. Thus, the net irrigation requirement is the difference between field capacity and the soil moisture content in the root zone before starting of irrigation. This may obtained by the relationship given below

$$d = \sum_{i=i}^{n} \frac{Mfci - Mbi}{100} \times A_i \times D_i$$

d = Net irrigation water to be applied (cm)

Mfci = FC in i^{th} layer (%)

Mbi = Moisture content before irrigation in i^{th} layer (%)

Ai = Bulk density (g/cc)

Di = depth (cm)

n = number of soil layer

Gross irrigation requirement (GIR):

The total quantity of water used for irrigation is termed gross irrigation requirement. It includes net irrigation requirement plus losses in water application and other losses. The gross irrigation requirement can be determined for a field, for a farm, for an outlet command area, and for an irrigation project, depending on the need, by considering the appropriate losses at various stages of water conveyance and distribution.

$$\text{GIR (in field)} = \frac{\text{Net irrigation requirement}}{\text{Field efficiency of the system}} \times 100$$

Irrigation interval (Irrigation frequency):

It is the number of days between two successive irrigations during the period without precipitation for a given crop and field. It depends on the crop ET rate and on the available water holding capacity of the soil in the crop root zone depth. Sandy soils require in general more frequent irrigations as compared to fine textured soils.

Irrigation period

It refers to the number of days that can be allowed for applying one irrigation to that of the next in a given design area during the period of highest consumptive use of the season.

Methods of Soil Moisture Estimation:

The measurement of soil moisture is needed to determine when to irrigate and how much water to be applied. For practical purpose, irrigation should be given when **about 50 percent** of available moisture in the root zone is depleted. The amount of water to be applied is directly related to the water already present in the soil.

The soil moisture is measured in two ways – direct and indirect methods as follows:

A) Direct method: Measurement of moisture content in the soil (wetness)

(1) Gravimetric Method (Oven dry method):

The method is extensively used for determination of moisture of the soil. In this method the soil moisture is expressed in oven dry weight basis. The soil sample in which the moisture content to be determined is taken from the field using the screw auger. The sample is transferred to an aluminium or stainless steel soil sample container. The weight of the sample container along with the soil sample is noted. Then it is placed in a hot air oven for 24-28 hours at 105 degrees centigrade. The dry weight of the soil sample with container is again weighed. From the dry and wet weights of the soil, moisture content can be calculated.

$$\text{Soil moisture \% by weight } (P_w) = \frac{\text{Wet soil weight} - \text{Dry soil weight}}{\text{Dry soil weight}} \times 100$$

(2) Volumetric Method

Soil sample is taken with a core sampler or with a tube auger whose volume is known. The amount of water present in soil sample is estimated by drying it in the oven and calculating by following formula.

Moisture content = Moisture content (%) by weight x Bulk Density (%) by volume.

The method is simple and reliable but time consuming and sampling is destructive.

B) Indirect methods:

In those methods, no water content in the soil is directly measured but the water potential or stress or tension under which the water is held by the soil is measured. The most common instrument used for estimating soil moisture by indirect method is:

(1) Tensiometer (Irrometers): Tensitometer developed by Richards and Gardner (1936). Tensiometer is widely used for measuring soil water tension in the field and laboratory. A tensiometer consists of a 7.5 cm long porcelain cup filled with water, which is connected to water filled glass tube, a vacuum gauge and a hollow metallic tube holding all parts together (At the time of installation, system is filled with water through the opening at the top and closed with a rubber cork). When installed in the soil at the required depth, water moves out through the porous cup till the surrounding soil is saturated. It creates a vacuum in the tube, which is measured in the vacuum gauge. When desired tension is reached, the field is irrigated. The tensiometer works satisfactory up to 0.85 bars of atmosphere.

(2) Gypsum block/Resistance block: Gypsum block developed by Bouyoucous & Mick (1940). This method is based on the principle that the electrical conductivity of porus blocks (made of plaster of paris / gypsum/ nylon/fiber glass) placed in soil is related to change in soil moisture content. They represent the soil as far as its soil moisture content is concerned and when electrical current is passed, the resistance to the flow of electricity is proportional to the moisture content of these blocks, i.e. of soil. This resistance is measured by a resistance meters. The resistance at field capacity various from 400 to 600 ohms and at wilting point it varies from 50,000 to 75,000 ohms. Nylon and fiberglass blocks are more sensitive in higher ranges of moisture. Plaster of paris blocks function effectively at tension between -1 and -15 bars. This method is relatively easy and quick to record the resistance of large number of sample. Salts or fertilizers in the soil affect the reading of the blocks.

3) Pressure membrane and pressure plate apparatus: Pressure membrane and pressure plate apparatus (developed primarily by Richards) is generally used to estimate field capacity, permanent wilting point and moisture content at different pressures. The apparatus consists of air tight metallic chamber in which porous ceramic pressure plate is placed. The pressure plate and soil samples are saturated and are placed in the metallic chamber. The required pressure, say 0.33 bar or 15 bars is applied through a compressor. The water from the soil sample which is held at less than the pressure, Applied trickles out of the outlet till equilibrium against applied pressure is achieved after that, the soil samples are taken out and oven dried for determining the moisture content.

(4) Neutron Moisture Meter (neutron scattering method): This is the rapid method of soil moisture determination in situ. The probe contains a sealed Americium-Beryllium radioactive source having fast neutrons. When this source comes in contact with soil, it emits fast neutrons into the soil and they collide with the hydrogen atoms in soil water causing the neutrons to scatter. Thus slow neutrons generated within the soil around is a function of soil moisture content. It is measured by boron trifluoride detector in the probe. This is amplified, displayed digitally as counts per second. The count rate is converted into soil moisture content by calibrations. This method is quick and accurate but involved high cost and risk of exposure to radioactive rays.

(5) Microwave remote sensing: it is new, promising and non- destructive approach for determination of water content in soil.

(6) Time-domain Reflactometer (TDR) – It is used for in-situ determination of water content using microwave radiation. The advantage of TDR method is that calibration curve is unaffected by factors such as soil texture, salinity, bulk density, temperature and organic matter.

<u>Methods of Estimation of Water Requirement/Measurement of Evapotranspiration (ET):</u>

Water requirement is greatly affected by various climatological, soil and crop factors and it varies from place to place and season to season. Estimation of water requirement is necessary for proper management of water resources and planning of irrigation schedules for different crops. Following methods may be adopted to estimate water requirement or evapo-transpiration or actual consumptive use.

1. Lysimeter Experiments

It is otherwise known as evapotranspiration meter. It is nothing but growing the crop in big containers (filled with soil) under natural conditions of the field to determine the water gain and loss to work out the evaporation and transpiration. In this method, ET is measured directly to study the climatic factors.

Weighing type - Here, the added water and water losses are weighed through the weighing balance fitted in the lysimeter. The weight difference is taken into account to measure the ET.

Non-weighing type - Here, the changes in the soil moisture at time intervals is measured by using neutron probe to work out the ET. In both the cases different sizes of lysimeter are available.

2. Field Experimental Plots

In this method, seasonal water requirement of crops is calculated. Water applied, the effective rainfall received during the season and contribution of soil moisture from the field are measured. Water needed during the crop season is the water requirement of the crop and is computed by using the formula.

$$WR = IR + ER + \sum_{i=1}^{n} \frac{Mbi - Mei}{100} \times BD_i \times D_i$$

WR = Seasonal water requirement (mm)   IR = Total irrigation applied (mm)

ER = Seasonal effective rainfall (mm)

Mbi = Moisture % at the beginning of the season in the ith layer of the soil

Mei = Moisture % at the end of the season in the ith layer of the soil

BDi = Bulk density of the soil in the ith layer of the soil (g/ cm^3)

Di = Depth of the ith layer of the soil within root zone (mm)

n = Number of soil layers in the root zone D

However, this is an accurate method but it is time consuming, laborious and costly.

3. Soil Moisture Depletion Studies

This is also known as depth-interval-yield approach in which experiments are conducted with variation in depth of irrigation (5-10 cm) at each irrigation and intervals (5-15 days) between irrigations. Consumptive use can be estimated by measuring soil moisture from various depths at periodical intervals during the crop growth period. Consumptive use is calculated from the change in soil water content in successive samples using following formula:

Where,

$$u = \sum_{i=1}^{n} \frac{Mfi - Msi}{100} \times BDi \times Di$$

u = water use from the root zone in successive sampling periods or within one irrigation cycle (mm)

Mfi = Soil moisture % at the time of first sampling in the ith layer of the soil

Msi = Soil moisture % at the time of second sampling in the ith layer of the soil

BDi = Bulk density of the ith layer of the soil (g/ cm^3)

Di = Depth of the ith layer of the soil (mm)

n = Number of soil layers sampled in the root zone D

The seasonal consumptive use is obtained by adding consumptive use values for each sampling interval. This is more accurate method, as actual depletion in soil moisture is estimated in the required depths.

4. Water Balance Method

This is also called as the inflow - outflow method which is suitable for larger areas (watersheds) over long periods. It is represented by the hydrological equation.

Precipitation = Evapotranspiration + surface run off + subsurface drainage + change in soil water contents.

5. Evaporimeters

Evaporimeters are simple device consisting of a pan with adequate water of known volume, wherein the loss of water is measured precisely by recording the reduction in its level by evaporation. They are used for estimating the potential evapotranspiration (PET) of various crops. Generally, three types of evaporimeters are used in India.

(a) U.S class A evopometer*:* It is most widely used evaporation pan. It is made of 20 gauge galvanized iron sheet 120 cm. in diameter by 25cm. in depth and is painted white and exposed on a wooden frame in order that air may circulate beneath the pan. It is filled with water to depth of about 20 cm. The water surface level is measured daily by means of hook gauge in a still well. Difference between two daily readings indicates the evaporation if there is no rainfall. When there is rainfall, record it separately with a rain gauge. Add that value to the initial water level in the still well. Difference between this reading and subsequent reading of the water would indicate evaporation. Water is added each day to bring the level to fixed point in the still well. A measuring cylinder can also be used for this purpose.

(b) Sunken screen evaporemetre: It developed by Sharma & Dastane (1968) at the I.A.R.I., New Delhi provides a simple device to make reasonable estimate of CU. It is used to measure ET under field conditions. It is determination of PET/ET ratio according to them varies from 0.95 to 1.05.

(C) Portable evaporimetre: It developed in Israel in 1984 to measure evaporation for very short periods.

Chapter-8

Evaporation, Transpiration, Evapo-transpiration, Potential-evapotranspiration, effective raifall and consumptive use of water and factors affecting it.

A) Evaporation (E)

Evaporation is defined as the process by which water moves out of the water surface or soil surface in the form of water vapour to atmosphere due to pressure gradient. It is an endothermic process requiring energy. The energy required for evaporation is 590 calories per gram of water to evaporate at 20oC.

B) Transpiration (T)

Transpiration is the process by which water evaporates in the form of water vapour from living plant body especially from leaves to atmosphere

C) Evapo-transpiration (ET) or Consumptive use

Evapotranspiration is the combined process of evaporation and transpiration in which water is lost from soil surface or water surface and that lost through leaves of Plant (from stomata).

Factors influencing Evapo-transpiration (ET)

Evapo-transpiration (ET) is influenced by atmospheric, soil, plant and water factors.

A) Atmospheric	**B) Soil factors**	**C) Plant factors**	**D) Water factors**
1. Precipitation 2. Sunshine 3. Wind velocity 4. Temperature 5. Relative humidity	1. Soil texture 2. Soil structure 3. Soil depth 4. Soil topography 5. Depth of water table 6. Available soil moisture 7. Vegetative cover	1. Plant morphology 2. Crop geometry 3. Plant cover 4. Stomatal density 5. Root depth 6. Growing season 7. Crop duration 8. Crop variety	1. Frequency of irrigation 2. Quality of water

Consumptive use of water (Cu or U)

This term is use to denote the amount of water that is used in metabolic activity of plant and the water lost through the process of evaporation and transpiration. But the water used for metabolic activity is negligible (1 per cent or less than 1 per cent of ET). Hence both term evapo-transpiration and consumptive use of water are simultaneously interchangeable in field of water and irrigation management.

Seasonal consumptive use of water

The total amount of water used in evaporation and transpiration by a crop during the entire growing season is called seasonal consumptive use. It is expressed as depth of water in cm or volume in ha / cm.

Potential Evapotranspiration (PET)

This concept was suggested by Thornthwait in 1948. It is the evapotranspiration from a large area fully covered with short vegetation with sufficient available water. It is also known as reference evapotranspiration and denoted as ET0.

Effective rainfall:

Dastane (1974) has defined effective rainfall as "A fraction of total precipitation that becomes utilizable for crop production.

Effective rainfall=Rainfall-(deep percolation + surface runoff)

Effective root zone depth

Soil depth from which the full grown crop can extract most of the water needed for Cu or ET is known as effective root zone depth. It is depth from which the roots of the average mature are capable of reducing soil moisture to the extent that it should be replaced by irrigation.

Factors influence the effective rainfall:

a) Rainfall characteristics: Large quantity as well as high intensity will reduce effectiveness because of excess run off and less infiltration rate. A well-distributed rainfall with some frequent light showers is more conducive to crop growth than downpour.

b) Land characteristics: Here, because of the slope very less infiltration opportunity time is available which results in rapid run off loss and less effective.

c) Soil characteristics: Properties like infiltration rate, retention capacity, releasing capability and movement of water influence the degree of effectiveness. High infiltration, high water holding capacity etc., increase effectiveness by avoiding run of losses. High moisture content, low infiltration rate, low water holding capacity reduces effectiveness.

d) Ground water characteristics: Shallow water table causes more run off and effectiveness is low. Deep water table causes more infiltration and percolation and effectiveness of rainfall is more.

e) Management practices: Bunding, terracing, ploughing, ridging and mulching reduce runoff and increase effective rainfall.

f) Crop characteristics: Crop with high water consumption creates greater deficits of moisture in the soil. The effective rainfall is directly proportional to the rate of water uptake by the plant.

Chapter-9

Water Use efficiency, Irrigation Efficiencies and factors affecting it

An efficient irrigation system implies effective transfer of water from the source to the filled with minimum possible loss. The objective of the efficiency concept is to identify the nature of water loss and to decide the type of improvements in the system. Evaluation of performance in terms of efficiency is prerequisite for proper use of irrigation water.

1. Irrigation Efficiency

It is defined as the ratio of water output to the water input, i.e., the ratio or percentage of the irrigation water consumed by the crop of an irrigated farm, field or project to the water delivered from the source.

$$Ei = \frac{Wc}{Wr} \times 100$$

where,

Ei = irrigation efficiency (%)

Wc = irrigation water consumed by crop during its growth period in an irrigation project.

Wr = water delivered from canals during the growth period of crops.

In most irrigation projects, the irrigation efficiency ranges between 12 to 34 %.

2. Water Conveyance Efficiency

It is the ratio between water delivered to the fields to amount of water diverted from source. It is mathematically expressed as:

$$Ec = \frac{Wt}{Wf} \times 100$$

where,

Ec = water conveyance efficiency, per cent

Wf = water delivered to the farm by conveyance system (at field supply channel)

Wt = water introduced into the conveyance system from the point of diversion

Water conveyance efficiency is generally low; about 21% losses occur in earthen watercourses only.

3. Water Application Efficiency

It is the ratio between quantity of water stored in the root zone to the amount of water delivered to the plot. It is mathematically expressed as:

$$Ea = \frac{Ws}{Wf} \times 100$$

where,

Ea = water application efficiency, per cent
Ws = irrigation water stored in the root zone of farm soil
Wf = irrigation water delivered to the farm (at field supply channel)

4. Water Storage Efficiency:

It is defined as the ratio of the amount of water stored in the root zone to the water needed in the root depth to bring it to the field capacity. Also termed as water storage factor.

$$Es = \frac{Ws}{Ww} \times 100$$

where,

Es = water storage efficiency, per cent
Ws = water stored in the root zone during the irrigation
Ww = water needed in the root zone prior to irrigation, i.e., field capacity available moisture

5. Water Distribution Efficiency

It is the ratio between the average numerical deviations in depth of water stored from average depth stored during irrigation (Y) and the average depth stored during irrigation (d).

$$Ed = \frac{(1 - y)}{D} \times 100$$

where,

Ed = water distribution efficiency, per cent
y = average numerical deviation in depth of water stored from average depth stored during irrigation
D = average depth of water stored along the run during irrigation

A water distribution efficiency of 80% means that 10% of water was applied in excess and consequently 10% was deficient in comparison to the average depth of application.

6. Consumptive Use Efficiency

It is defined as the ratio of consumptive water use by the crop to the amount water stored in the root zone of the soil. After irrigation water is stored in the soil, it may not be available for use by the crop because water may evaporate from the ground surface or continuously move downward beyond the root zone as it may happen in wide furrow spacing. The loss of water by deep penetration and by surface evaporation following irrigation is evaluated from the following expression:

$$Ecu = \frac{Wcu}{Wd} \times 100$$

where,

Ecu = consumptive use efficiency, per cent
Wcu = normal consumptive use of water
Wd = net amount of water depleted from root zone soil

7. Water Use Efficiency (WUE)

It is the yield of marketable crop produced per unit water used in evapo-transpiration (ET). It is expressed in kg/ha-mm.

Water use efficiency of are two types as (i) **crop water use efficiency and (ii) field water efficiency.**

(a) Crop Water Use Efficiency: It is the ratio of yield of crop (Y) to the amount of water depleted by crop in the process of evapotranspiration (ET).

$$CWUE = \frac{Y}{ET}$$

where, CWUE= Crop water use efficiency

Y= Crop yield ET = Evapotranspiration

It is expressed in kg/ha/mm or kg/ha/cm.

(b) Field Water Use Efficiency:

It is the ratio of yield of crop (Y) to the total amount of water used in the field (WR).

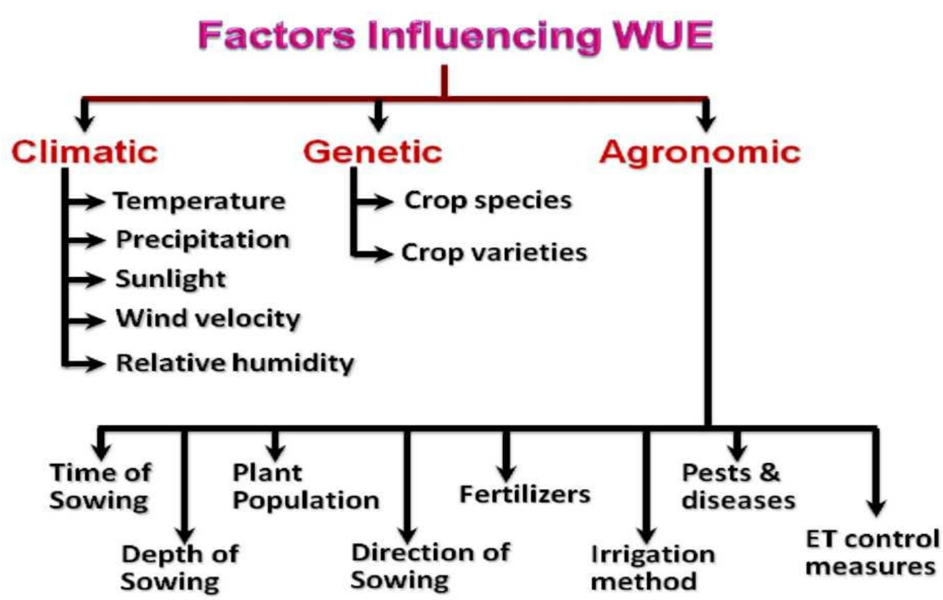
$$FWUE = \frac{Y}{WR}$$

where,

FWUE = field water use efficiency

WR = water requirement

Factors affecting on Water use efficiency:



Measures/ Ways to improve water use efficiency:

A. Climatic factors: Plant transpiration and soil evaporation are dependent upon the temperature, wind velocity, relative humidity, sunshine hours and rainfall of a particular area. Evapotranspiration is directly correlated with temperature and wind velocity thereby reducing WUE. Similarly, evaporation is inversely proportional to humidity of climate which results in reduced consumption of water thereby increasing water use efficiency. Increased availability of light to plants increases photosynthesis resulting in greater production which consequently increases WUE of crops.

B. Nature of crops: Crops with higher canopies have greater growth and consequently higher photosynthesis which results in greater yield and concomitant higher WUE. Plants with shallow and less developed roots are able to absorb less water and fertilizers resulting in their lesser growth and production. Consequently, their WUE is reduced.

C. Cultural practices: Cultural practices which directly affect WUE are as under

1) Sowing time: The crops sown at proper time have greater production and hence higher water use efficiency. The crops grown latter have lesser growth and development produce low yield and hence lesser WUE.

2) Method of sowing: Compared to broadcasting method of sowing of crops, line sowing of crops has greater utilization and absorption of nutrients, water and light resulting in higher production which results in higher WUE. Grain yield of wheat, oats and pearlmillet were also increased when crops were sown in the N-S direction.

3) Depth of sowing: Crops whose seeds are sown at optimum depth have greater growth since germination and hence higher production resulting in greater WUE.

4) Use of antitranspirants: Antitraspitants are those materials whose spray upon plants reduced transpiration. Kaolin, phenyl mercuric acetate and abscisic acid are a few well known anti-transpirants. The spraying of anti-transpirantsupon plants results in their reduced transpiration which lessons their consumptive use thereby increasing WUE.

5) Use of growth retardants: Experiments have proved that there exist certain chemical substances like cycocel (CCC), phosphon etc. whose praying upon plants in good production despite lack of water. Hence, it generates higher WUE.

6) Use of mulch: Mulches refers to the artificial or natural materials covered on the surface of soil with a object to reduce evaporation and destruction of weeds resulting in greater use of light, fertilizers, air and water by crops which results in higher production consequently higher WUE.

7) Method of irrigation: Compared to flooding method of irrigation, sprinkling and drip methods of irrigation results in lesser loss of water through evaporation and infiltration etc. which results in greater production using less water thereby increasing their WUE.

9) Fertilizer application: The optimum application of fertilizers at proper time increases the growth the development of crops thereby increasing their WUE.

10) Weed control: Weeds always compete with crops for the use of water, nutrients, air and light. Hence, destruction of weeds through proper methods is essential for the proper growth of crops and their consequent higher WUE.

11) Insect-pest and disease control: The insect-pest and disease management at proper time is imperative for production of a good crop. If crops are not saved from insect-pest and other diseases, their growth and development is lessened resulting in reduced WUE.

12) Use of shelter belts: There is greater irrigation water loss in areas having hot and high velocity winds through evaporation. In such area, use of shelter belts helps to reduce evaporation loss of water and ultimately increases WUE.

Besides all above factors, certain factors like crop rotation, soil testing, seed treatment, soil and water management practices, addition of organic matter in the soil and type of soil etc. which also affects the WUE of crops.

Chapter-10

Criteria for scheduling of irrigation, Methods of irrigation, advantages, disadvantages.

Irrigation scheduling

"Irrigation scheduling is the process of determining when to irrigate and how much water to apply".

Importance of irrigation scheduling

1. For maximize water use efficiency
2. To maximize yield
3. To increase cropping intensity
4. Improve and quality produce
5. To maintain soil and environmental balance

Approaches/Criteria of irrigation scheduling:

Approaches /Criteria for schedule irrigations		
A) Soil moisture regime approaches	**B) Climatological approaches**	**C) Plant indicator approaches**
1. Soil water content approach 2. Depletion of available soil moisture 3. Soil water potential or soil moisture tension	1. PET measurement 2. IW/CPE approach	1. Visual plant symptoms 2. Plant water content 3. Leaf diffusion resistance 4. Plant temperature 5. Critical crop growth stage

1) Soil moisture depletion approach:

The available soil moisture in the root is a good criterion for scheduling irrigation. When the soil moisture in a specified root zone depth is depended to a particular level (which is different for different crops) it is too replenished by irrigation. **For practical purpose, irrigation should be started when about 50 percent of the available moisture in the soil root zone is depleted.** The available water is the soil moisture, which lies between field capacity and wilting point. The relative availability of soil moisture is not same field capacity to wilting point stage and since the crop suffers before the soil moisture reaches wilting point, it is necessary to locate the optimum point within the available range of soil moisture, when irrigation must be scheduled to maintain crop yield at high level. Soil moisture deficit represents the difference in the moisture content at field capacity and that before irrigation. This is measured by taking into consideration the percentage, availability, tension, resistance etc.

Dr. A.S. Chavan, Assistant Professor of Agronomy

2) Climatological or Meteorological approach:

Evapotranspiration mainly depends up on climate. The amount of water lost by evapotranspiration is estimated from Climatological data and when ET reaches a particular level, irrigation is scheduled. The amount of irrigation given is either equal to ET or fraction of ET. Different methods in Climatological approach are IW/CPE ratio method and pan evaporimeter method.

IW /CPE Approach

Prihar et al. (1974) developed IW:CPE approach. In IW/CPE approach, a known amount of irrigation water is applied when cumulative pan evaporation (CPE) reaches a predetermined level. The amount of water given at each irrigation ranges from 4 to 6 cm. The most common being 5 cm irrigation. Scheduling irrigation at an IW/CPE ratio of 1.0 with 5 cm. Generally, irrigation is given at 0.75 to 0.8 ratios with 5 cm of irrigation water. The irrigation scheduling is based on the cumulative pan evaporation and irrigation depth.

Irrigation at ratio of irrigation water (IW) and cumulative pan evaporation (CPE).

$$\text{IW /CPE ratio} = \frac{\text{Depth of water to be irrigated (IW)}}{\text{Cumulative pan evaporation for particular period (CPE)}}$$

Sunken Screen Evaporinreter: In order to simplify the measuring device of ET, Dastane and Sharma (1968) at IARI, New Delhi has developed sunken screen evaporimeter. They observed a ratio of evaporation and evapotranspiration (Eo/ET) to be 0.95 to 1.05 that is more precise measurement of ET compared to USWB pan evaporimeter. They suggested the use of still smaller evaporimeter such as can evaporimeter with 1 kg capacity and a pointer inside at 1.5 cm below the brim to facilitate the recording of water. The consumptive use may be computed from the following formula:

Evapotranspiration = Pan evaporation x Crop factor.

3) Plant basis or plant indices:

As the plant is the user of water, it can be taken as a guide for scheduling irrigation. The deficit of water will be reflected by plants itself such as dropping, curling or rolling of leaves and change in foliage colour as indication for irrigation scheduling. However, these symptoms indicate the need for water. They do not permit quantitative estimation of moisture deficit. Growth indicators such as cell elongation rates, plant water content and leaf water potential, plant temperature leaf diffusion resistance etc. are also used for deciding when to irrigate. Some indicator plants are also a basis for scheduling irrigation e.g. sunflower plant which is used for estimation of PWP of soil is used in Hawaii as an indicator plant for irrigation sugar cane.

Critical stage or phenological stage approach

The stage at which the water stress causes severe yield reduction is also known as **critical stage of water requirement**. It is also known as **moisture sensitive period**. Under limited water supply conditions, irrigation is scheduled at moisture sensitive stages and irrigation is skipped at non-sensitive stages. In cereals, panicle initiation, flowering, and pod development are the most important moisture sensitive stages.

Table : Moisture sensitive stages of Important Crops

Crops	**Critical stages / Sensitive stages**
Rice	Panicle initiation, flowering and milky stage
Sorghum	Flowering and grain formation
Maize	Silking, tasseling
Pigeon pea	Flower initiation and pod formation
Groundnut	Flowering, pegging, and pod development
Greengram	Flower initiation and pod formation
Cotton	Flowering, boll formation
Wheat	Crown root initiation (CRI), jointing, milking
Chickpea	Pre-flowering, pod development
Mustard	Branching, siliqua development
Sunflower	Two weeks before & after flowering
Soybean	Blooming and seed formation
Safflower	Rosette to flowering
Sugarcane	Formative stage

Plant water status:

This is the latest approach for scheduling of irrigation. Plant is a good indicator of a soil moisture and climate factors. The water content in the plant itself is considered for scheduling irrigation. It is however, not yet common use for want of standard and low cost technique to measure the plant water status or potential.

METHODS OF IRRIGATION:

Irrigation methods refers to the manner in which water is applied to the land. Different methods are used to apply irrigation water to the crop depending on the source of supply of water, topography, quantity of water to be applied, the crop and method of cultivation of crop. These irrigation methods are classified as surface, sub-surface, sprinkler (over-head) and drip method of irrigation.

Methods of irrigation-

1. Surface methods- a. Wild flooding
   b. Check basin
   c. Ring Basin method
   d. Border strip
   e. Furrow method-1. Corrugation
   f. Surge irrigation
2. Sub surface irrigation
3. Sprinkler/ overhead irrigation
4. Drip/ Trickle irrigation
5. Automated Irrigation System

I. Surface Irrigation

It is the common method of irrigation practiced all over the world. In this method, water is applied directly to the surface by providing some checks to the water flow:

I. Surface irrigation

1. Wild or Free Flooding

1. Used for lowland rice and other crops.
2. Water is allowed from the channel into the field without much control on either sides of the flow.
3. It covers the entire field and move almost unguided.
4. The height of bunds around the field should be 15 cm for effective use of rainfall.
5. It is a minimum labour intensive method.
6. Most suitable to irrigated saline soils.

Advantages

1. Easy and cheap method
2. Skilled person is not required for controlling the water flow

Disadvantages

1. Wasteful use of water,
2. non-uniform distribution of water,
3. excessive soil erosion on steeper slopes and
4. Require drainage arrangement to reduce ponding.

2. Border Strip (Sara) method

- The land is divided into number of long parallel strips called borders.
- These borders are separated by low ridges.
- The border strip has a uniform gentle slope in the direction of irrigation.
- Each strip is irrigated independently by turning the water in the upper end.
- The water spreads and flows down the strip in a sheet confined by the border ridges.
- The application efficiency of this system is 75–85%.

- Not suited for very sandy soil and very clayey soil as they have too high and low infiltration rate, respectively.

Advantages

1. Uniform and even distribution of water
2. High water application efficiency
3. Large irrigation streams can be efficiently used
4. Good surface drainage
5. Less labour required for field lay out and irrigation.
6. Due to longer strip size inter-cultivation is possible.

Limitations

1. Require labour for layout of system
2. Expensive and time consuming
3. It is not suitable for sandy soils.

3. Check basin irrigation

Flooding of relatively leveled plots surrounded by borders is known as check basin method.

- It is the most common method in which the field is divided into smaller unit areas so that each has a nearly level surface.
- Bunds or ridges are constructed around the area forming basins within which the irrigation water can be controlled.
- The water applied to a desired depth can be retained until it infiltrates into the soil.
- The size of the basin varies from 4 m x 3 m to 6 m x 5m (10 m^2 to 25 m^2) depending upon soil type, topography, stream size and crop.

Advantages

1. Check basins are useful when leaching is required to remove salts from the soil profile.
2. water can be retaining for desired depth
3. High water application and distribution efficiency.

Limitations

1. The ridges interfere with the movement of implements.
2. More area occupied by ridges and field channels.
3. The method impedes surface drainage
4. Precise land grading and shaping are required
5. Labour requirement is higher
6. Not suitable for crops which are sensitive to wet soil conditions around the stem.

4. Furrow irrigation

It is the common method adopted for row planted crops like cotton, maize, sugarcane, potato, beetroot, onion, sorghum, vegetable crops etc. In this method, small evenly spaced shallow furrows or channels are formed in the beds. Another method of furrow irrigation is forming alternate ridges and furrows to regulate water. The water is turned at the high end and conveyed through smaller channels. Water applied in furrows infiltrate slowly into the soil and spread laterally to wet the area between furrows. The dimension of furrows depend on the crop grown, equipment used and soil type. The length of the furrow ranges from 50 to 400 m and 'U' shaped furrows are better than 'V' shaped furrows. In heavy soils, furrows can be used to dispose the excess water.

Advantages

1. Water in furrows contacts only one half to one fifth of the land surface.
2. Labour requirement for land preparation and irrigation is reduced.
3. Compared to check basins there is less wastage of land in field ditches.
4. Reduces evaporation lossess
5. High water use efficiency

Disadvantages:

1. Requires laboures to open furrows
2. Costly system
3. Leveling of field is necessary
4. Interculture operation is difficult

5. Ring basin

This method is mostly adopted for wide spaced orchard crops. The rings are circular basins formed around the individual trees. The rings between trees are interlinked with main lead channel by sub channels to get water to the individual rings. As water is allowed in rings only, wastage of water spreading the whole interspaces of trees as in the usual flooding irrigation method is reduced. Weed growth in the interspaces around the rings are discouraged. This method ensures sufficient moisture in the root zone and saves lot of irrigation water.

6. Surge Method

1. **Intermittent application of water** to the field surface under gravity flow which results in a series of "**On and Off**" modes of constant or variable time spans.

Advantages

1. Infiltration uniformity is increased,

2. Deep percolation is reduced compared to continuous water application due to intermittent wetting and drying process.

7. Cablegation: It is a automated method of irrigation.

II. Sub-surface (sub-soil) irrigation

Water is applied below the ground surface through the network of pipes or some devices. The main aim of this type of irrigation is to reduce the evaporation loss and to maintain an artificial water table near the root zone of the crop.

- In subsurface irrigation, water is applied through under ground perforated pipes or through deep trenches at 15-30 m interval.
- Water gradually wets root zone through capillary movement / action.
- Open ditches are preferred because they are relatively cheaper and suitable to all types of soil.
- The irrigation water should be of good quality to prevent soil salinity.

- ♦ It is suitable where water table is shallow.

Advantages

1. Minimum water requirement for raising crops
2. Minimum evaporation and deep percolation losses
3. No wastage of land
4. No interference to movement of farm machinery
5. Cultivation operations can be carried out without concern for the irrigation period.

Disadvantages

1. Requires a special combination of natural conditions.
2. There is danger of water logging and deep percolation through trenches
3. Possibility of choking of the pipes lay underground.
4. Initial cost is very high.
5. Maintenance of pipelines is difficult.

III. Pressurized Irrigation System

Micro-irrigation:

It is defined as the precise and slow application of water over a long period of time in the form of discrete or continuous or tiny streams of miniature sprays through mechanical devices directly into plant root zone, via a low presser delivery system.

Eg. Drip irrigation, micro-jet irrigation, micro-sprinkler and bubbler irrigation etc.

1. Drip (Trickle) Irrigation

Drip or trickle irrigation is one of the latest methods of irrigation. Drip (Trickle) irrigation system was developed in 1964 by Symcha Blass, an Israeli Engineer. It is defined as the precise and slow application of water in the form of discrete or continuous or tiny streams of miniature sprays through mechanical device called emitters or drippers located at selected points along water delivery lines.

- ➢ It is suitable for water scarcity and salt affected soils.
- ➢ Water is applied in the root zone of the crop

Standard water quality test needed for design and operation of drip irrigation system.

Components of Drip Irrigation

A drip irrigation system consist essentially of main line, submains, laterals, drippers (emitters), filters and other small fitting and accessories like value, presser, regulators, presser gauge, fertilizer application components etc.

1) Pump

The pump creates the pressure necessary to force water through the components of the system including the fertilizer tank, filter unit, main line, lateral and the emitters/ drippers. The lateral may be designed to operate under pressure as low as 0.15 to 0.2 kg/cm^2 and as large as 1 to 1.75 kg/cm^2. The water coming out of the emitters is almost at atmospheric pressure. The duty of the pump in terms of flow and pressure is determined after the diameter, length and discharge of all the mains, laterals and emitters are decided and the friction losses are estimated.

2)Filter

It is the heart of drip irrigation system. Filtration of irrigation water is essential to prevent clogging of emitters which can be a major problem in the system. The clogging may be due to presence of salts in water, microorganisms, suspended organic and inorganic matter, clays, silt etc., filter is connected to the central distribution system. There are two common types of filters:

3)Screen (mesh) filter

This is useful primarily for removing suspended inorganic particle s in water containing sufficient amount of organic matter. The screen filter does not remove large amounts f suspended particles and organic particles without reducing the flow of water through the filter. It is therefore, necessary to frequently flush the screen mesh filter to remove accumulated particles.

4)Sand (Gravel) filter

Sand filter is most effective in the removal of inorganic and organic particles from water. It can extract and retain large quantity of suspended solids without reduction in delivery of the rated flow of filtrated water. The sand filter is normally provided with a back flushing arrangement.

5)Main line

The mainline conveys the water from filtration system to the submain. They normally made of rigid PVC pipes in order to minimize corrosion and clogging. Usually they are placed below the ground i.e. 60 to 90 cm (2 to 3 ft) so that will not interfare with cultivation practices. The main line system has changing flow capacity with respect to length. The mains are PVC pipes usually of 25 mm to 75 mm in diameter.

6)Sub-main

Sub-main distributes the same discharge to all the laterals fitted to it. They are also buried in ground 2 to 2.5 ft and made up of rigid PVC. The diameter is smaller than mainline. There are number of submains from one mainline depending upon the plot size and crop type. Usually pipes of 25-50 mm diameter and suitable length are used.

7)Laterals

Laterals are provided in the main line or sub-main for each row of the crop. Laterals are small diameter flexible pipes or tubing made of low density polythene (LDP) and linear low density polythene (LLDPE) and of 12 mm, 16 mm and 20 mm size. Their color is black to avoid the algae growth and effect of ultra violet radiation. On slopping ground, the laterals are placed along the counter with 1% extra for sagging purpose.

8)Drippers/ Emitters

It is the main component of drip irrigation system for discharging water from lateral to soil i.e. plant. They are made of plastic such as polythene or polypropaline**.** The discharge rate of emitters ranges from 1 to 15 liters per hour (LPH). Emitters may be on the lateral or inside the lateral, accordingly they are called as online or inline emitters.

9)Control valve (Ball valves)

These are used to control the flow through particular pipes. Generally they are installed on filtration system, main line and on all submains. These are made up of gunmetal, PVC, cast iron and their size ranges from ½" to more than 5".

10)Flush valves

It is provided at the end of each submain to flush out the water bad dirts.

11)Air release cum vaccum breaker valves

It is provided at the highest point in the main lines to release the entrapped air during the stars of system and to break the vaccum during shut off. It is also provided on submain if submain length is more.

12)Non return valves

It is used to prevent the damage of pump from back flow of water hammer in rising main lines.

13)Presser gauge

It is used to indicate the operating presser of the drip system.

14)Grommet and take off

These are used to connect the lateral to submain. A hole is punched with hand drill of predetermined size in submain. Grommet is fixed in to the hole. Takeoff is pressed in to the grommet with takeoff punch up to the step provided. Grommet acts as a seal. The sizes are different for 12 mm, 16 mm and 20 mm lateral.

15)End caps (End sets)

These are used to close the lateral ends, submain ends, or main line end. Submains and mains are preferably provided with flush valve. They are convenient for flushing the line.

Advantages of Drip Irrigation

1. Well suited for areas of acute water shortage.
2. Minimization of soil erosion and deep percolation and runoff losses.
3. Water is maintained at field capacity.
4. Salt concentration is less.
5. No land leveling is necessary.
6. Herbigation and Fertigation can also be applied.
7. Less disease and weed infestation.

Disadvantages of Drip Irrigation

1. High initial cost on plastic pipes as extensive pipe net work is needed.
2. Drippers are susceptible to blockage and difficult to locate the clogging.
3. Interferes with farm operations and movement of implements and machineries.
4. Frequent maintenance is required.
5. Requires the clean water for irrigation.
6. Not suitable for closed spaced crops.

Fertigation:

This is the process of applying fertilizers through the irrigation system. The soil is negatively charged at high pH and $PO4^{-}$ will be precipitated with Ca+ and absorbed with clay. Availability of P is very low as time proceeds due to this precipitation. Fertigation is problematic at high pH because the availability of micronutrients (Fe, Mn, etc.) is less due to the precipitation. Hence iron chelates (Sequestrene -138) are applied which prevents Fe from precipitation. Also zinc chelates are good to prevent Zn precipitation.

ADVANTAGES

1. Eliminates manual application
2. Quick and convenient
3. Uniformity in application
4. High efficiency and saving of fertiliser upto 30 - 40%
5. Less fel1ilizer leaching
6. Better penetration of P and K in the layers
7. Co-ordination of nutrition requirement with crop stage or development
8. Possibility of dosage control.
9. Others like herbicides, pesticides, acid, etc can also he applied

LIMITATIONS

1. Toxicity to field workers
2. Chance of backflow into water source, for that NRV and vacuum valve has to be installed
3. Insoluble fel1ilisers are not suitable (super phosphate)
4. Corrosive effect of fertiliser
5. Phosphate may get precipitated in the pipe line and dripper due to pH reaction
6. High cost

2. Sprinkler/over head Irrigation System

The sprinkler irrigation system conveys water from the source to the field through pipes under pressure and distribute over the field in the form of sprays of rain like droplets. In other words, the method of applying water to the surface of the soil in the form of spray, similar to rains, is known as sprinkler irrigation system. It is also known as overhead irrigation.

- This system is designed to distribute the required depth of water uniformly, which is not possible in surface irrigation.
- Water is applied at a rate less than the infiltration rate of the soil hence the runoff from irrigation is avoided.

Components of Sprinkler System

1)Pumping unit

A high speed centrifugal or turbine pump can be installed for operating the system for individual farm holdings. The pump usually lift water from the source and pushed it through the distribution system and sprinkler..

2)Main lines

Main pipelines carry water from the pumping plant to many parts of the field. In some cases sub main lines are provided to take water from the mains to laterals.

3)Lateral lines

The lateral pipelines carry the water from the main or sub main pipe to the sprinklers. The pipelines may be either permanent, semi permanent or portable.

4)Couplers

A coupler provides connection between two tubing and between tubing and fittings.

5)Sprinkler Head

Sprinklers may rotate or remain fixed. The rotating sprinklers can be adapted for a wide range of application rates and spacing. They are effective with pressure of about 10 to 70 m head at the sprinkler. Pressures ranging from 16-40 m head are considered the most practical for most farms. Fixed head sprinklers are commonly used to irrigate small lawns and gardens.

6)Debris screen

The function of screens is to keep the system free of trash that might plug the sprinkler nozzles

7)Booster pump

Booster pump should be used when a sprinkler irrigation system is used with an exsinting pumping system installed in a well and the pump capacity is insufficient to forece the water through sprinkler.

8)Take off valves

These are generally needed to control the presser in the lateral lines. The valves should always used in where there are significant differences in main line presser at the various laterals take off points.

9)Flow control valves

Flow control valves are used to regulate the presser and discharge of individual sprinkler and may be helpful to equal distribution of presser along the lateral.

Other accessories / fittings

1. Water meters: It is used to measure the volume of water delivered.
2. Pressure gauge: It is necessary to know whether the sprinkler is working with the desired pressure in order to deliver the water uniformly.
3. Bends, tees, reducers, elbows, hydrants, butterfly valves, end plugs and risers
4. Debris removal equipment: This is needed when water is obtained from streams, ponds, canals or other surface supplies. It helps to keep the sprinkler system clear of sand, weed seeds, leaves, sticks, moss and other trash that may otherwise plug the sprinklers.
5. Fertilizer applicators: These are available in various sizes. They inject fertilizers in liquid form to the sprinkler system at a desired rate.

Advantages of Sprinkler System

1. Uniform distribution of water.
2. Saving of water from 25-50 per cent.
3. Saving of land 10-20 per cent.
4. Irrigation area is increased by 1-2 times with the same amount of the water.
5. No risk of runoff and erosion.
6. Suitable for undulating land and steep sloppy.
7. Suitable for areas where water and labour scarcity.
8. Suitable for saline soils to leach salts.

Disadvantages of Sprinkler System

1. Not followed under high wing velocity (>12 km/hour).
2. High initial costs.
3. High energy is required (0.50 to >10 kg/cm2).
4. More spreading of diseases.
5. Can not be used for rice and jute crops.

5. Automated Irrigation System (Based on Microcontroller)

- Irrigation is the artificial application of water to the land or soil.
- Irrigation system uses valves to turn irrigation ON and OFF. These valves may be easily automated by using controllers and solenoids.
- In this system an attempt has been made to automate farm or nursery irrigation that allows farmers to apply the right amount of water at the right time, regardless of the availability of labor to turn valves on and off.
- In addition, farmers using automation equipment are able to reduce runoff from over watering saturated soils, avoid irrigating at the wrong time of day, which will improve crop performance by ensuring adequate water and nutrients when needed.
- The Microcontroller based automated irrigation system consists/components:
  1. Moisture sensors,
  2. Analog to digital converter,
  3. Microcontroller,
  4. Relay driver,
  5. Solenoid valve,
  6. Solar panel and a battery.
- This system can be used in the areas where electrical power is difficult to obtain.
- This system is eco friendly and it uses a renewable source of energy.
- It also helps in time saving, removal of human error in adjusting available soil moisture levels and to maximize their net profits.

Chapter-10

Water Quality parameters, Water logging, Causes of water logging, Management of water logged soils.

Pure water is rare in nature. Whatever may be the source of irrigation water, some soluble salts are always dissolved in it. The main soluble constituents in water are Ca, Mg, Na and K as cations and chloride, sulphate, bicarbonate and carbonate as anions. However, ions of other elements such as lithium, silicon, bromine, iodine, cobalt, fluorine, boron, titanium, vanadium, barium, arsenic, antimony, beryllium, chromium, manganese, lead, selenium phosphate and organic matter are also present. Among the soluble constituents calcium, sodium, sulphate, bicarbonate and boron are important in determining the quality of irrigation water and its suitability for irrigation purposes. However, other factors such as soil texture, permeability , drainage, type of crop etc., are equally important in determining the suitability of irrigation water.

Surveys have shown that 1.5 m ha area is affected with poor quality of water in several states of India. The most affected state is Rajasthan. In the world, over 50 million ha are affected by salinity spread over 24 countries.

PROBLEMS OF POOR QUALITY WATER

Use of poor quality irrigation water has adverse effect on soil, nutrient availability, crop growth and soil microorganisms.

1. High sodium content in irrigation water causes deflocculation of soil leading to reduced permeability and hence low infiltration of water to the root zone. Soil crusting and water logging reduce oxygen supply to the root zone.
2. High concentration of Ca reduces the uptake of potassium by the plants.
3. High concentration of Mg induces calcium deficiency. High sulphate content reduces uptake of Ca and increase sodium uptake leading to Na toxicity.
4. Soil salinity affects cell division, cell elongation and protein synthesis. It affects the structure and and integrity of plant membrane and cuases mitochondria and chloroplast to swell. Na and Cl at toxic level disrupt the structure of the protein molecules. High Cl content hinders the development of xylem tissue.
5. Exessive soluble salt concentration in the root zone restrict plant water uptake leading to physiological drought. The reduction in yield due to salinity is more in warm climate than cool climate.
6. High content of boron, chloride, sodium, sulphate and bicarbonate in irrigation water cause toxicity to the plant leading to poor growth and yield.

7. Beneficial microorganisms are sensitive to high salt contents. Nitrate and nitrite producing bacteria are sensitive to high salt concentration than ammonia producing bacteria. Azotobacter is relatively resistance to high salt concentration.

Quality of Irrigation Water:

The criteria for judging the quality of irrigation water are: total salt concentration as measured by electrical conductivity, relative proportion of sodium to other cations as expressed by sodium absorption ratio, bicarbonate content, boron concentration and soluble sodium percentage.

CLASSIFICATION OF IRRIGATION WATER

1. Salinity hazard (Total concentration of soluble salts)

Classification of irrigation water based on EC

Class	EC (dS/m)	Quality rating	Suitability for soil and crops
C_1	< 0.25	Low salinity water	Most soil and all crops but leaching is required for extremely low permeable soil
C_2	0.25 - 0.75	Medium salinity water	Most crops (moderate salt tolerance) on medium light texture soil having moderate permeability and leaching to avoid accumulation of salts.
C_3	0.75 - 2.25	High salinity water	Tolerant crops on light and medium textured soils by providing good drainage and required agronomic practices for salinity control.
C_4	> 2.25	Very high salinity water	Not suitable for irrigation only salt tolerant crops. May be used occasionally in permeable soil by providing adequate drainage.

2. Sodium hazard (Relative concentration of Na relative to other cations)

Sodium adsorption ratio (SAR): A ratio to express in soil extracts and in irrigation water, the relative activity of sodium ions in exchange reactions with soil.

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

Classification of irrigation water based on SAR

Class	SAR	Quality rating	Suitability for soil and crops
S_1	< 10	Low sodium	Most soil and all crops with little danger of the development of Na problem
S_2	10-18	Medium sodium	Most crops (moderate tolerant) on soils of coarse texture and with lot of organic matter.
S_3	18-26	High sodium	Semi tolerant crops and light textured soils requires good drainage, high leaching and addition of organic matter.
S_4	> 26	Very high sodium	Not suitable for irrigation except at low and medium salinity. Gypsum has to be added to decrease sodium hazard appreciably.

3**. RSC hazard (Bicarbonate concentration relative to Ca^{+2} + Mg^{+2})**

RSC rating	Quality rating	Suitability for soil and crops
< 1.25	Good water	If RSC is -ve, then water is of very good quality.
1.25 - 2.5	Marginal good	It can be used on light textured soil with adequate leachning and application of gypsum.
> 2.5		Not suitable for irrigation.

4. Boron hazard

Boron at low concentration is not harmful to the crops and is essential micronutrient for plant growth. It is toxic beyond 2 ppm to the most of the field crops.

Boron content (ppm)	Tolerance	Crops
0.3 - 1.0	Sensitive crops	Apple, grape, orange, lemon, grape fruit
1.0 - 2.0	Semi sensitive crops	Sunflower, potato, cotton, radish, field pea, barley, wheat, corn, sweet potato
2.0 to 4.0	Tolerant crops	Palm, date palm, sugarbeet, Lucerne, onion, turnip, cabbage, lettuce, carrot

MANAGEMENT AND USE OF POOR QUALITY WATER

Management practices for using poor quality water

Some of the important management practices are as follows:

a) Application of gypsum: Chemical amendments such as gypsum, when added to water will increase the calcium concentration in the water, thus reducing the sodium to calcium ratio and the SAR, thus improving the infiltration rate.

b) Alternate irrigation strategy: Some crops are susceptible to salinity at germination & establishment stage, but tolerant at later stage. If susceptible stages are ensured with good quality water, subsequent tolerant stages can be irrigated with poor quality saline water.

c) Fertilizer application: Fertilizers, manures, and soil amendments include many soluble salts in high concentrations. If placed too close to the germinating seedling or to the growing plant, the fertilizer may cause or aggravate a salinity or toxicity problem. Application of fertilizers in small doses and frequently improve uptake and reduce damage to the crop plants. In addition, the lower the salt index of fertilizer, the less danger there is of salt burn and damage to seedlings or young plants.

d) Methods of irrigation: Poor quality irrigation water is not suitable for use in sprinkler method of irrigation. Crops sprinkled with waters having excess quantities of specific ions such as Na and Cl cause leaf burn. High frequency irrigation in small amounts as in drip irrigation improves water availability and uptake due to micro leaching effect in the wetted zone.

e) Crop tolerance: The crops differ in their tolerance to poor quality waters. Growing tolerant crops when poor quality water is used for irrigation helps to obtain reasonable crops yields.

f) Method of sowing: Seeds have to be placed in the area where salt concentration is less. Salt accumulation is less on the slope of the ridge and bottom of the ridge. Therefore, placing the seed on the slope of the ridge, several cm below the crown, is recommended for successful crop establishment.

g) Drainage: This is necessary to avoid build of salt in the soil solution to levels that will limit crop yields. Leaching requirement can be calculated from water test results and tolerance levels of specific crops.

Waterlogging/Drainage of Water

For optimum growth and yield of field crops, proper balance between soil air and soil moisture is quite essential. Except rice many of the cultivated plants cannot withstand excess water in the soil. The ideal condition is that moisture and air occupy the pore spaces in equal proportions. When the soil contains excess water than that can be accommodated in the pore spaces it is said the field is water logged.

Causes of water logging

1. Excessive use of water when the water is available in abundance or cheaply due to the belief that more water contributes better yield.
2. Improper selection of irrigation methods.
3. Percolation and seepage from lands canals and reservoir located at nearby elevated places.
4. Improper lay out and lack of outlets.
5. Presence of impervious layer with profile impeding percolation.
6. Upward rise of water from shallow ground water table or aquifer.
7. Ingress of sea water to adjacent lands.

8. Floods in rivers spread to cultivated land during high storms and cyclones causes water logging.

Effects of water logging

Direct effects

1. Replacement of soil air which is the main source of oxygen for the roots as well as soil microbes.
2. Due to high amount of CO_2 in soil air resulted in high CO_2 concentration under water logged condition will kill plant roots.
3. Sometimes superficial root system or air space in root system will develop.
4. Due to poor aeration intake of water and nutrient will be reduced.

Indirect effects

1. Reduces the availability of N, Mn, Fe, Cu, Zn, Mo.
2. Reduces soil temperature
3. Reduces the activity of beneficial microbes
4. Destruct soil structure
5. Difficult for cultural operations
6. Incidence of pest, disease and weeds

Effect of drainage on soil improvement and crop growth: (Advantages of drainage)

1. To provide suitable conditions for better plant growth.
2. Agricultural land can be used for using time without deterioration of soil structure.
3. It lowers the underground water table so as to facilitate increased root zone depth.
4. It improves aeration and increase soil temperature.
5. Drainage for agricultural land provide by surface and subsurface drainage.

Methods of drainage

There are three general types of land drainage systems

A) Surface drainage, which removes excess surface water from the fields

B) Sub surface drainage, which removes excess water from the crop root zone depth of the soil.

C) Bio-drainage through plants

A) Surface drainage

1) Interception drains
2) Diversion drains
3) Bedding system
4) Random system

5) Parallel system

6) Field system drains

B) Subsurface drainage

1) Pipe or tile drainage

2) Mole drainage

3) Deep open drains

A) Surface drainage

Removal of free water tending to accumulate over the soil surface is called surface drainage. In this system a slope of free water surface is develop so as to remove excess water from the land surface also, surface drainage is classified on the basis of slope and is depends on the topography of the land soil characteristics and crops that are grown.

Interception drains : It is adopted in sloping area (slope exceeding 2%). it consists of a shallow open drains across the slope with a mild grade to intercept and remove surface runoff it is also known as cross slope ditch system.

Random system: It is used where small scattered depressions to be drained occur over the area. It is designed to connect one depression to another depression (ditch) and water is conveyed to an outlet. Also open drains besides occupying land area are interface in farming operations.

Diversion Drains: The channel is excavated across the slope to divert runoff and sub surface flow and drains are replaced by open ditches which are relatively deeper with steeper side slopes than the field drains.

Bedding system: This system is adopted when the slope of land does not exceed (0.5 per cent to 1.5 per cent). This system is essentially land forming process. In this system, the land is ploughed into beds, separated by dead furrows, which run in the direction of prevailing slope. Ploughing is to be done parallel to the furrow. Bedding was proved to be successful on poorly drained soils. The bed width depends upon the land use, slope of the field, soil permeability form operations.

Parallel system: It is most effective method of surface drainage and is well suited both for irrigated and rainfed areas. In this system individual fields are properly graded such that they discharge into field drains. The field drains may discharge into field laterals in turn to the main. Laterals and mains should be deep than field ditches to provide free outfall.

Field Drains: The functioning of open drains depends on their proper maintenance, if neglected. It may lead to Sedimentation, Growth of vegetation, Bank erosion,damage to side slope.

Sedimentation of drains is mainly due to sediment moving into drains along with surface runoff. Sediment inflow can be minimized by watershed erosion control. Construction of silting basins and low check dams are recommended to reduce the rate of sedimentation. Weed growth reduces drainage channel capacity. Damage by bank erosion and side slope damage occure due to topographical conditions through which drain has to pass. Timely control measures are necessary to maintain the open drains for effective drainage.

B) Subsarfae drainage : Subsurface drainage refers to the natural outflow or to the artificial disposal of excess water within the soil or sub soil and it, generally, involves lowering the water table or preventing its rise. It is also known as ground water drainage.

1. Tile drainage: This consists of continuous line of tiles laid at a specific depth and grade so that the excess water enters through the tiles and flow out by gravity. Laterals collect water from soil and drain into sub main and then to main and finally to the out let. Tile drains are made with clay and concrete, Tiles should be strong enough to withstand the pressure and also resistant to erosive action of chemicals in soil water.

2. Mole drainage: Mole drains are unlined circular earthen channels formed within the soil by a mole plough. The mole plough has a long blade like shank to which a cylindrical bullet nosed plug is attached known as mole. As the plough is drawn through the soil the mole forms the cavity to a set depth. Mole drainage is not effective in the loose soil since the channels produced by the mole will collapse. This is also not suitable for heavy plastic soil where mole seals the soil to the movement of water.

C) Bio-Drainage:

- Bio-drainage may be defined as, "pumping of excess soil water using bio-energy through deep –rootd vegetation with high rate of transpiration".
- The bio-drainage consist of fast growing tree species, which absorb water from the capillary fringe located above the ground water table.
- The absorbed water is translocated to different parts of plants and finally more than 98% of the absorbed water is transpired into the atmosphere mainly through the stomata.
- This combined process of absorption, translocation and transpiration of excess ground water into the atmosphere by the deep rooted vegetation conceptualizes bio-drainage.

Advantages of bio-drainage:

a. Less costly to raise bio-drainage plantations
b. No maintenance cost from 3rd year onward
c. No operational cost, as plants use their bio-energy in draining out excess water into atmosphere.
d. Increase in worth with age instead of deprecation.
e. No need of any drainage outfall and disposal of drainage effluent.
f. No environmental problem/Environmental safety
g. In-situ solution for the water logging and salinity.

Suitable species for bio-drainage may be *Eucalaptus spp. Casuarina glauca*, *Terminalia arjuna*, *Pongamia pinnata* and *Syzygium cuminii*, etc.

Chapter-13

Crop management techniques in problematic areas i.e. saline, alkaline, acidic soils.

WATER MANAGEMENT IN PROBLEM SOILS

When rocks and minerals undergo weathering process, large quantities of soluble salts are formed. In humid regions, these salts are washed down to the ground water and to the sea. But in arid and semiarid regions they accumulate in the soil. Excessive irrigation and poor water management are the two chief causes of water logging and salt accumulation. Accumulation of salts in soil leads to unfavourable soil-water-air relationship and affect the crop production.

A. Causes for Salt Accumulation

The following are the main causes which lead to development of salty soils (Salinity or alkalinity).

(*i*) **Arid climate -** About 25% of earth surface is arid in which salt accumulation is a common problem. In India, about 25 m.ha are salt affected with different degrees of degradation.

(*ii*) **High subsoil water table -** When the water table is within the capillary range, the water containing soluble salts rises to surface. When the water evaporates the salts are deposited as encrustation. It is estimated that in Punjab, annually about 50,000 acres becomes saline because of raising water table.

(*iii*) **Poor drainage -** Due to poor drainage, accumulation of water leads to water logging condition, which leads to salt accumulation.

B. Quality of Irrigation Water

Irrigation water containing more than permissible quantities of soluble salts with sodium carbonate and bicarbonates make the soil salty.

Inundation with sea water - In coastal areas, periodical inundation of land by sea water during high tides makes soil salty. Besides, deep bore wells are also the reason for saline soils.

Nature of parent rock minerals - The saline nature of parent rock minerals leads to salt accumulation.

Seepage from canals - The continuous seepage leads to salt accumulation.

Classification of Problem Soils:

Parameters	Saline soil	Alkaline soil	Saline-Alkali/Sodic
pH	<8.5	>8.5	>8.5
EC (ds/m at 25 oC)	>4	<4	>4
ESP	<15	>15	>15

The soil problems can also be divided into: (*a*) Chemical, (*b*) Physical.

(*i*) Soil chemical problems - The salt affected soils can be classified based on their ESP, pH and EC as follows:

Reclamation of saline soil - Leaching or flushing with good quality of water provided, there should be good drainage system should be there to flush water.

Reclamation of alkali soil - By converting exchangeable sodium into soluble salts by adding the following amendments.

- Calcium chloride
- Calcium sulphate (gypsum)
- Sulphuric acid
- Ferrous sulphate
- Aluminium sulphate

Reclamation of saline alkali soil - The reclamation of these soils is similar to that of alkali soils. First step is to remove the exchangeable sodium and then the excess salts and sodium are to be leached out. Commonly salt affected soils are referred as problem soils as indicated above. Further, based on pH value it can also be grouped as acid soils where the pH value is less than 7.

(*ii*) **Soil physical problems -** Fluffy soils, ill drained soils, soils with high infiltration rate, soils with shallow depth and encrustation in soil surface are the possible physical problems. Too frequent irrigation in clayey soils with very high water retention results in poor drainage, water logging and crop damage. Excess irrigation and heavy rain create hardening of soil surface in red lateritic soils with high Fe and Al hydroxides and low organic matter. This results in soil crusting. This leads to poor germination, restriction of shoot and root development and slow entry of water into the soil profile.

Management - In light soils, shallow depth of water with more frequency should be adopted. To increase the infiltration rate in clay soil, amending the soil by mixing with coarse textured soil or tank silt at the rate of 50 tones per hectare is advocated. Organic wastes like crop residue, farm waste, coir pith, filter cake etc., at the rate of 20 tones per hectare once in every year can be applied. Poorly drained clay soils can be improved by providing tile drains and trenches intermittently. To make the soil more permeable and to overcome poor drainage, addition of organic wastes or sandy soil at the rate of 20–50 tones per ha, respectively is advocated. The encrustation problem could be alleviated by incorporating organic matter and adding montmorilonite clay containing silt.

Terms/Glossary:

Sr. No.	Term	Definitions/Descriptions
1	**Irrigation**	Artificial application of water to the soil to escape stress of plant is called as irrigation
2	**Cusec**	Quantity of water flowing at rate of cubic foot per second.
3	**Consumptive use**	Quantity of water loosed by due to evapo-transpiration (ET) and that is used by plant for its metabolic activity.
4	**Effective rainfall**	A fraction of total precipitation that becomes utilizable for crop production.
5	**Hectare cm water**	A volume of water necessary to fill an area of 1 hectare of land to a depth of 1 cm. 1 ha. cm = 100 m^3 = 1,00,000 litres.
6	**Net irrigation requirement** (NIR)	It is the amount of irrigation water required to bring the soil moisture level in the effective root zone to field capacity.
7	**Irrigation efficiency**	It is the ratio of water stored in the soil for crop growth and total water applied.
8	**Hygroscopic water**	Hygroscopic water is that which is absorbed from an atmosphere of water vapour as a result of attractive forces in the surface of particles.
9	**Delta**	Delta is the total depth of water (cm) required by a crop during its duration in the field.
10	**Seepage**	Horizontal flow of water in irrigation channels or through canals.
11	**PET (Potential evapo-transpiration):**	It is amount of water evapo-transpired in unit time from a short uniform green crop growing actively and covering an extended surface and never short of water.
12	**Soil moisture tension**	Force at which water is held by the soil or negative pressure or suction that must be applied to bring the water in a porous cup into static equilibrium with the water in the soil.
13	**Bulk density**	It is the oven dry weight of unit volume of soil includes pore space and organic matter.

Sr. No.	Term	Definitions/Descriptions
14	**Fertigation**	Application of fertilizer through irrigation water.
15	**Adhesion**	Attraction between two dissimilar particles. Eg. Soil+water.
16	**Evapo-transpiration**	Quantity of water transpired by plant during their growth plus moisture evaporated from soil and vegetation.
17	**Available water**	It is the difference between the field capacity and permanent wilting point referred to as the available water or moisture.
18	**Percolation**	Vertical or downward movement of water from different soil layer, generally occurs in water saturated soil.
19	**Irrigation interval**	Time between the start of successive field irrigation applications on the same field; days.
20	**Infiltration**	The downward movement of water into the soil, generally occurs in unsaturated soil.
21	**Base**	The period (days) during which irrigation water is supplied to the crop.
22	**Water management**	The integrated process of intake, conveyance, regulation, measurement, distribution, application of irrigation water to the field at right times, quantity and method and removal of excess water from the field for the purpose of securing maximum crop production and water economy.
23	**Micro-irrigation/ Drip irrigation**	The precise and slow application of water over a long period of time in the form of discrete or continuous or tiny streams of miniature sprays through mechanical devices directly into plant root zone, via a low presser delivery system.
24	**Water requirement**	The total amount of water required at the field head regardless of it source, to mature a crop.
25	**Drainage**	It is the process of removal of excess water as free or gravitational water from the surface and the sub surface of farm lands with a view to avoid water logging and creates favourable soil conditions for optimum plant growth.

Sr. No.	Term	Definitions/Descriptions
26	**Soil moisture constant**	Water available in the soil at standard crop growth stage is called soil moisture constants.
27	**Water use efficiency**	It is the ratio of Crop yield (Y) to the amount of water used by the crop for evapotranspiration (ET).
28	**Sodium adsorption ratio (SAR)**	A ratio to express in soil extracts and in irrigation water, the relative activity of sodium ions in exchange reactions with soil.
29	**Permeability**	The ability of soil to movement of air and water.
30	**Field capacity**	The moisture content present in the soil after the drainage of water due to gravitational force is stopped or ceased or become very slow.
31	**Bio-drainage**	Pumping of excess soil water using bio-energy through deep –rootd vegetation with high rate of transpiration.
32	**Irrigation scheduling**	"Irrigation scheduling is the process of determining when to irrigate and how much water to apply".
33	**SPAC**	The complete path of water from the soil through the plant to the atmosphere forms a continuous system referred as **Soil-plant atmospheric continuum (SPAC).**
34	**Duty of water**	Volume or quantity of water required for irrigation to bring a crop to maturity.
35	**Soil texture**	Relative proportions of mineral particles of various sizes in a given soil volume.
36	**Particle density**	Ratio of a given mass (or weight) of soil solids to that of its volume.
37	**Transpiration ratio**	The amount of water transpired by a crop in its growth to produce a unit weight of dry matter.
38	**Soil moisture characteristic curve**	A curve showing relationship between the energy status of water (tension) and amount of moisture in soil.
39	**Water-logging**	When soil contains excess water than that can be accommodated in the pore spaces, it is said the field is water logged.

Fill in blanks

Sr. No.	Fill in blanks
1	Size of clay particles less than **0.002** mm
2	Available water percentage at PWP is **25-50 %.**
3	One ha-cm of water equal to **1 lakh lit./100 m^3** of water.
4	Gypsum block works on principle of **conductance of electricity.**
5	The amount of water metabolically used by plants is **1%**.
6	The annual precipitation of India is **8 m** ha excluding rainfall.
7	At field capacity, Available Soil Moisture is **100 %**.
8	In sorghum, moisture sensitive stress stage is **Booting/panicle initiation.**
9	According to rooting depth, rice is classified as **shallow** 60 cm rotted crop.
10	Among the surface irrigation methods, **check basin** layout saves maximum water.
11	Sprinkler irrigation suited in **sands and sandy loams** soils have high infiltration rate.
12	***Eucalaptus spp*** is most appropriate plant for biodrainage.
13	The portion of total rainfall which directly satisfies crop water need is called **Effective rainfall.**
14	The total rainfall (75-80%) in the country is contributed by **South-West** monsoon.
15	The downward entry or movement of water from the surface into the soil is referred as **Infiltration.**
16	Hygroscopic water is held on soil particles in between **31-10,000** atm.
17	The ratio of a given mass of of an oven dried soil that of its field volume (i.e. solids+pore spaces) is referred as **Bulk density**.
18	Attraction between water molecules and solid surfaces is known as **Adhesion.**
19	At field capacity, the soil moisture tension depending on the soil texture ranges **0.10 to 0.33** bars.
20	The amount of soil moisture held between the two cardinal points viz. field capacity (0.33 bars) and PWP (15 bars) is called **available soil moisture**.
21	For determination of PWP **sunflower** plant is used.
22	Generally irrigation may be given at **50** percentage of depletion of available soil

	moisture.
23	At field capacity, available soil moisture is **100** percent.
24	**Micro** pores serve as major channel for movement of gravitational water.
25	The period between two successive irrigations is known as **irrigation interval**.
26	Soil attains the field capacity in **48 to 72** hrs after saturation.
27	1 bar=**0.99 atm** / 1023 cm of water
28	Drip nozzles are called as **Emitters/Drippers**.
29	Water requirement= consumptive use+ **application losses**+ amount of water required for special needs.
30	**Field capacity** is the upper limit of available soil moisture.
31	Flow of water @ one cubic foot/sec is known as **Cusec**.
32	Tensiometre is also called as **irrometre**.
33	**Capillary** water is useful for crop plants.
34	Removal of excess water from the soil is called as **drainage**.
35	**Check basin** method of irrigation is followed to irrigate wheat crop.
36	Moisture held by soil colloids is termed as
37	Average rainfall of India is **1190** mm.
38	In gravimetric method, soil samples are dried in an oven at **105 ^{0}C** temperature.
39	Tensiometre works satisfactorly upto **0.8** bar.
40	Application of fertilizer through trickle irrigation system is known a **Fertigation**.
41	Water required for metabolic activities of plants is less than **1%** of ET.
42	In Maharashtra, irrigated area is **16.40** percent of cultivated area.
43	The crop coefficient values are higher during **reproductive** growth stage.
44	Gravitational water is held at **0.3** atmosphere tension by soil.
45	Pan evaporation X **kc** = potential evapotranpiration.

46	**5 ha cm** is the average depth of irrigation for surface irrigation methods.
47	Amongst surface irrigation methods, **border strip** method saves the maximum irrigation water.
48	The moisture extraction pattern shows that moisture extracted from the first quarter of the rootzone is **40 percent**.
49	Available water percentage at PWP is **25-50** %.
50	One hectare centimeter water equal to **100** m^3 of water.
51	Sprinkler method is particularly suited to **sandy soils** that having infiltration rate.

Match the pairs with answers

Sr. No.	A	B
1	Sunflower plant	Indicator plant
2	Gypsum block	Boycos and Mick
3	Hygroscopic co-efficient	31 atmosphere
4	Drip irrigation	Emitter
5	PWP	15 atmosphere
6	Soil texture	physical property of soil
7	Tensiometre	Richard and gardner
8	Shallow soil	sprinkler irrigation
9	Parshall flume	Lit/sec
10	Tensiometre	Atmosphere
11	Gypsum block	Ohms
12	Bulk density	g/cc
13	Irrigation efficiency	Per cent
14	Neutron moisture metre	Probe and rate metere
15	Percolation	Downward movement of water
16	Field capacity	1/3 rd bar
17	Duty of water	Cusec
18	Consumptive use of water	ET
19	Climatelogical approach	Scheduling irrigation
20	Passive absorption	Transpiration
21	Total depth of water required by crop	Delta
22	Retention of water	Imbibitional water
23	Reshaping of surface to a desired elevation and slope	Land leveling
24	Hygroscopic water	31 to 10,000 atmosphere

State true or false

Sr No.	Statement	True/False
1	Sprinkler irrigation is also called as trickle irrigation	False
2	Average rainfall of India is 1094.00 mm	True
3	Finer soil has lower water holding capacity	False
4	Tensiometre developed by richards and gardner	True
5	The amount of water metabolically used by plants is 50 %.	False
6	Sprinkler irrigation suited to black cotton soil	False
7	Among irrigation methods, surface irrigation is most efficient method	True
8	CRI (Crown root initiation) stage is critical for wheat crop	True
9	Practically consumptive use of water is equal to evapo-transpiration	True
10	In waterlogging, supply of oxygen to crop restricted	True
11	Sunflower plant is used to irrigation scheduling	True
12	C4 plants have high WUE	True
13	Loss of water through plant body is called evapotranspiration	False
14	Tensiometre works satisfactorily in clay soil	False
15	Total capillary water is useful for crop growth and thereby crop production.	False
16	Drip irrigation system can not be used effectively on hill slopes.	True
17	Runoff loss of water is more in sandy soil than clay soils	True
18	Water holding capacity of soil is increased by addition of OM.	True
19	It is recommended to carry out tillage operations when the soil moisture content is less than field capacity	True
20	The neutron moisture meter does not work satisfactory if soil is rich in organic matter content	True
21	In case of check basin method, the surface drainage can not be provided.	True
22	In feel and appearance method, the field capacity, the squeezing of soil sample at field capacity will squeeze out free water.	False
23	Sprinkler irrigation is also called as trickle irrigation.	False