02. ROLE OF WATER IN PLANT GROWTH – HYDROLOGICAL CYCLE - WATER IN SOIL - PLANT - ATMOSPHERE CONTINUUM - ABSORPTION OF WATER AND EVAPOTRANSPIRATION

IMPORTANCE OF WATER – THE LIQUID GOLD

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

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

A) Physiological importance

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

B) Ecological Importance

- It helps to maintain soil temperature

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

The multifarious uses of good quality water for the purpose of irrigation, industrial purposes, power generation, livestock use, domestic use for urban and rural development, are increasing the demand for water. Due to increasing cost of irrigation projects and limited supply of good quality water, it becomes high valuable commodity and hence it is stated as Liquid Gold. Further, historical evidences indicate that all civilization established on water base due to proper management and disappear due to improper management of the same water base. All the superior varieties, organic manure, inorganic fertilizer, efficient labour saving implements, better pest and disease management techniques can be implemented only when sufficient water is applied to the crop. The diversified value of water can be quoted as follows:

Water as a source of sustenance
Water as an instrument of agriculture
Water as a community good
Water as mean of transportation
Water as an industrial commodity
Water as a clean and pure resource
Water as a beauty

Water as a destructive force to be controlled

Water as a fuel for urban development

Water as place for recreation and wild life habitat

As indicated by Sir.C.V.Raman water is the ELIXER of Life which makes wonders in earth if it is used Properly, Efficiently, Economically, Environmentally, Optimally, Equitably and Judicially.

Hydrological Cycle

Solid – liquid- gaseous form (refer any standard book)

State of water as solid – ice, its temperature – presence as ice, icebergs and Ice Mountains, ice glaciers and their role on water availability

As water – ocean – extent of ocean – their role on water availability

Gaseous form – clouds and their formation – precipitation – forms of precipitation etc.

Water in Soil - plant - atmosphere continuum

Soil physical properties influencing irrigation

Soil is a three-phase system comprising of the solid phase made of mineral and organic matter and various chemical compounds, the liquid phase called the *soil moisture* and the gaseous phase called the *soil air*. The main component of the solid phase is the soil particles, the size and shape of which give rise to pore spaces of different geometry. These pore spaces are filled with water and air in varying proportions, depending on the amount of moisture present. The presence of solid particles, liquid (soil solution) and gas (soil air) constitute a complex polyphasic system. The volume composition of the three main constituents in the soil system varies widely. A typical silt loam soil, for example, contains about 50 per cent solids, 30 per cent water and 20 per cent air. In addition to the three basic components, soil usually contains numerous living organisms such as bacteria, fungi, algae, protozoa, insects and small animals which directly or indirectly affect soil structure and plant growth. The most important soil properties influencing irrigation are its infiltration characteristics and water holding capacity. Other soil properties such as soil texture, soil structure, capillary conductivity, soil profile conditions, and depth of water table are also given consideration in the management of irrigation water.

Water Relations of Soil

The mineral and organic compounds of soil from a solid (though not rigid) *matrix,* the interstices of which consists of irregularly shaped pores with a geometry defined by the boundaries of the matrix (Fig. 7.5). The pore space, in general, is filled partly with soil air and liquid vapour and partly with the liquid phase of soil water. Soil moisture is one of the most important ingredients of the soil. It is also one of its most dynamic properties. Water affects intensely many physical and chemical reactions of the soil as well as plant growth.

The properties of water can be explained by the structure of its molecule. Two atoms of hydrogen and one atom of oxygen combine to form a molelargely determined by that of the oxygen ion. The two hydrogen ions take up practically no space. Water molecules do not exist individually. The hydrogen in the water serves as a connecting link from one molecule to the other.

Soil serves as the storage reservoir for water. Only the water stored in the root zone of a crop can be utilized by it for its transpiration and buildup of plant tissues. When ample water is in the root zone, plants can obtain their daily water requirements for proper growth and development. As the plants continue to use water, the available supply diminishes, and unless more water is added, the plants stop growing and finally die. Before the stage is reached when crop growth is adversely affected, it is necessary to irrigate again. The amount of water to be applied to each irrigation, and the frequency of irrigation are dependent on the properties of the soil and the crop to be irrigated.

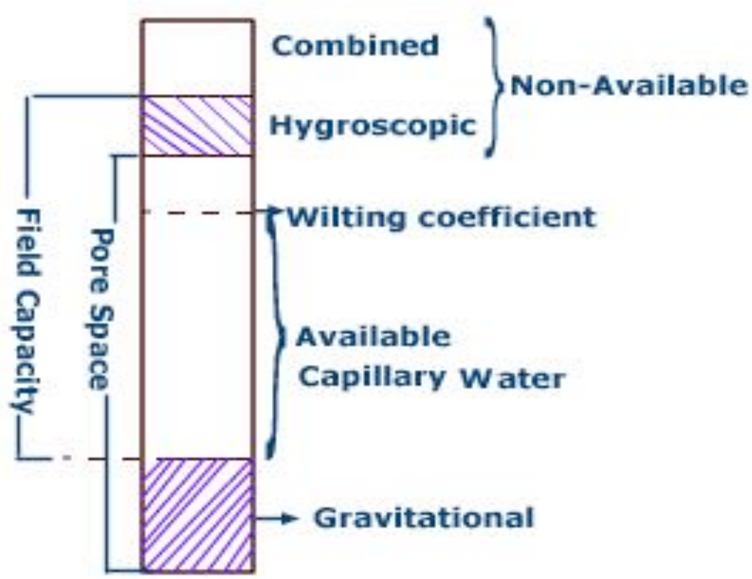
Kinds of soil water: When is added to a dry soil either by rain or irrigation, it is distributed around the soil particles where it is held by adhesive and cohesive forces; it displaces air in the pore spaces and eventually fills the pores. When all the pores, large and small, are filled, the soil is said to be saturated and is at its maximum retentive capacity. The following re the three main classes of soil water:

(i) Hygroscopic water. Water held tightly to the surface of soil particles by adsorption forces.

(ii) Capillary water. Water held by forces of surface tension and continuous films around soil particles and in the capillary spaces.

(iii) Gravitational water. Water that moves freely in response to gravity and drains out of the soil.

Adhesion is the attraction of solid surfaces for water molecules. Adhesion is operative only at the solid-liquid interface and hence the film of water established by it is very thin. Cohesion is the attraction of water molecules for each other. This force makes possible a marked thickness of the films of water established by hydration until they attain microscopic size. As the film gets thicker and thicker the forces of gravity act and water flows downward through the large pores. Such water is loosely held. Thus, when a soil is near saturation it is easy to remove an increment of water, but as moisture becomes less



and less in the soil, the greater will be the force required to remove a unit amount of moisture.

When a dry soil samples is exposed to water vapour, it will take up moisture. The amount adsorbed depends on the nature and magnitude of the surface exposed the temperature and the degree of humidity. The moisture thus adsorbed is the water of hydration, water of adhesion, or commonly the hygroscopic water. When the air saturation is 100 per cent the maximum amount of such moisture will be acquired.

The capillary water is held between tensions of about 31 atmospheres and one-third atmosphere. Between 31 and 15 atmospheres, capillary adjustment is very sluggish. Comparatively easy movement does not occur until the water film thickens and pressures near one-third atmosphere are reached. As a result of its energy relations, the capillary water is the only fluid water bearing solutes, that remains in the soil for any length of time, if drainage is satisfactory. Thus, it functions physically and chemically as the soil solution. The principal factors influencing the amount of capillary water in soils are the structure, texture and organic matter. The finger the texture of the mineral soil particles, the greater is likely its capillary capacity. Granular soil structure produces higher capillary capacity. Presence of organic matter increases the capillary capacity.

Water held in the soil at tensions of one-third atmosphere or less will respond to gravity and move downward, hence the name gravitational water. The water thus affected is that present in the non-capillary (large) pores. Of the three forms of water, only capillary and gravitational water are of interest to the irrigationists since hygroscopic water is not available to plants.

Movement of water into soils: The movement of water from the surface into the soil is called *infiltration*. The infiltration characteristics of the soil are one of the dominant variables influencing irrigation. *Infiltration rate* is the soil characteristic determining the maximum rate at which water can enter the soil under specific conditions, including the presence of excess water. It has the dimensions of velocity.

The actual rate at which water is entering the soil at any given time is termed the *Infiltration velocity*.

The infiltration rate decreases during irrigation. The rate of decrease is rapid initially and the infiltration rate tends to approach a constant value. The nearly constant rate that develops after some time has elapsed from the start of irrigation is called the *basic infiltration rate.*

Factors Affecting Infiltration Rate

The major factors affecting the infiltration of water into the soil are the initial moisture content, condition of the soil surface, hydraulic conductivity of the soil profile, texture, porosity, and degree of swelling of soil colloids and organic matter, vegetative cover, duration of irrigation or rainfall and viscosity of water. The antecedent soil moisture content has considerable influence on the initial rate and total amount of infiltration, both decreasing as the soil moisture content rises. The infiltration rate of any soil is limited by any restraint to the flow of water into and through the soil profile. The soil layer with the lowest permeability, either at the surface or below it, usually determines the infiltration rate. Infiltration rates are also affected by the porosity of the soil which is changed by cultivation or compaction. Cultivation influences the infiltration rate by increasing the porosity of the surface soil and breaking up the surface seals. The effect of tillage on infiltration usually lasts only until the soil settles back to its former condition of bulk density because of subsequent irrigations.

Infiltration rates are generally lower in soils of heavy texture than on soils of light texture. The influence of water depth over soil on infiltration rate was investigated by many workers. It has been established that in surface irrigation, increased depth increases initial infiltration slightly but the head has negligible effect after prolonged irrigation. Infiltration rates are also influenced by the vegetal cover. Infiltration rates on grassland is substantially higher than bare uncultivated land. Additions of organic matter increase infiltration rate substantially. The hydraulic conductivity of the soil profile often change during infiltration, not only because of increasing moisture content, but also because of the puddling of the surface caused by reorientation of surface particles and washing of finger materials into the soil. Viscosity of water influences infiltration. The high rates of infiltration in the tropics under otherwise comparable soil conditions is due to the low viscosity of warm water.

Soil Moisture Retention and Movement

The moisture content of a sample of soil is usually defined as the amount of water lost when dried at 105^0C, expressed either as the weight of water per unit weight of dry soil or as the volume of water pr unit volume of bulk soil. Although useful, such information is not a clear indication of the availability of water for plant growth. The difference exists because the water retention characteristics may be different for different soils.

The forces that keep soil and water together are based on the attraction between the individual molecules, both between water and soil molecules (adhesion) and among water molecules themselves (cohesion). In the wet range surface tension is the most important force, while in the dry range adsorption is the main factor. Thus, the higher the moisture content, the smaller is the attraction of the soil for water. The energy of water tension in a soil depends on the specific surface as well as the structure of the soil and on its solute content. When water is present in fine capillaries, the energy with which it is attached is a function of the surface tension and capillary size but when it is present in bigger pores, it is bound loosely to the soil and can be acted upon by gravity. When salts dissolve in water, they decrease the free energy of water. Soil water, by virtue of the salts dissolved in it has a lower free energy than pure water. Further, soil water that is bound to solid particles as hygroscopic water is tightly held by the surface of contact and has a low free energy by virtue of binding forces. Thus, there are two types of interactions which decrease the free energy of water, namely, (i) due to the solubility of salts, (ii) due to the interaction of water and solid surface. Both these add together in decreasing the energy of soil water. Thus, the retention of water in the soil and the tendency of water to move in the soil are consequences of energy effects.