UNIT 2 CROP WATER REQUIREMENT

Structure

2.1 INTRODUCTION

India is a country with various landforms ranging from lofty mountains to ravine, deltas and also including high altitude forest of Himalayas, sprawling grasslands of Indo-Gangetic plains, peninsular plateaus of South-East and South-West India and many other geological formations. The climate of India is full of extremities; for example, its temperature varies from arctic cold to equatorial hot and rainfall from extreme aridity with less than 100 mm in Thar Desert to per-humid with world's maximum rainfall of 11200 mm at Mowsinram in the state of Meghalaya. Due to presence of a wide range of geological and climatic conditions, Indian agriculture is diverse and complex with both irrigated and dry land areas, capable of producing most of the food and horticultural crops of the world. For the purpose of planning, better management of natural resources to curb environmental degradation and to give impetus to the agricultural productivity for food and nutritional security to its ever increasing population, the country has been grouped into 20 agro-climatic regions and 60 agro-ecological sub-regions on the basis of soil, agro-ecological conditions and physiographic situations. India has an estimated 142 million hectare (Mha) cultivated area of which about 57 Mha is irrigated and remaining 85 Mha is rain-fed. The cropping intensity is stagnating at 1.35, which could be increased with increase in irrigation and mechanization particularly in the eastern part of India. Rice, wheat, maize, sorghum, and millet are the five main cereals grown in India. Along with this the pulses, oilseeds, cotton, jute, sugarcane, and potato are the other major crops. Pulses include mainly gram (chickpea) and pigeon pea and oilseeds include mainly groundnut, mustard and rapeseeds, soybean, and sunflower. Each crop requires water at different stages of crop growth. Water requirement depends on the crop type, season existing soil moisture and other related factors. Crops like sugarcane grown in heavy soils require the more water, whereas crop like wheat and other grains require less amount of water and are grown in sandy loam soil. The crop like cotton, maize requires normal quantity of water.

Objectives

After studying this unit, you should be able to

- understands crop seasons, water requirements of different crops, critical stages at which irrigation is required and irrigation scheduling,

- describe irrigation efficiencies and their importance in water management, and
- define terms used in water planning and their relation ship, command area – both gross and cultivable, intensity of irrigation and irrigable area.

2.2 CROP SEASONS – KHARIF AND RABI

Traditionally, there are three cropping seasons – rabi, kharif and zaid. Rabi cropping season extends from October-November to March-April, Kharif from June-July to September-October. Zaid season spans during interregnum period between rabi and kharif. Major rabi crops are wheat gram, pea and major kharif crops are paddy and jowar. In fact, rice-wheat is the most important crop rotation covering nearly 69.3 million hectare area out of which wheat cultivation was undertaken in 26.3 million hectare during the year 2005, with a production of 72 million tonnes (FAO, 2005). Punjab Haryana and western UP having major arable land with assured irrigation, are main regions cultivating rice-wheat crop rotation. There is wide variation in climatic situation in the country so there is remarkable variation in cropping seasons also. In Maharashtra, there are five cropping seasons. The limits for each season are fixed by irrigation department.

Table 2.1 : Crop Seasons

Season	Period From-To	Base Period Days)	Common Crops
Kharif	15^{th} June-14^{th} Oct	123	Rice, Jowar, Cotton, Tur, Udid, etc.
Rabbi	15^{th} Oct-14^{th} Feb	122	Wheat, Gram, Linseed, etc.
Hot weather	15^{th} Feb-14^{th} June	120	Only irrigated crops like vegetable
Eight Monthly	15^{th}June-14^{th} Feb	245	Tobacco, Cotton, Tur, Groundnut, etc.
Annual	15^{th} June-14^{th} June Next	365	Sugarcane, Orchards, etc.

2.3 WATER REQUIREMENTS FOR DIFFERENT CROPS

The term water requirements of a crop means the total quantity of all water and the way in which a crop requires water, from the time it is sown to the time it is harvested. The water requirement of crop varies with the crop as well as with the place. The same crop may have different water requirements at different places of the same country; depending upon the climate, type of soil, method of cultivation and useful rainfall. For better understanding of crop water requirement, it is prudent to have knowledge of functions of irrigation water.

2.3.1 Functions of Irrigation Water

(a) Irrigation water acts as a nutrient carrier and supplies moisture to the soil, which is essential for the growth of bacteria, beneficial for the growth of plants.

(b) The moisture facilitate chemical actions within the plant leading to its growth.

(c) It controls the temperature of soil and makes more favourable environment for the healthy growth of the plants. It also softens the tillage pans.

(d) Irrigation water with controlled supplies dilutes the salts present in soil.

The total water requirements of crops depend on the following factors :

(a) Type of soil

(b) Temperature and wind

(c) Rainfall and wind.

(d) Crop

(e) Method of cultivation.

(f) Water management.

Water requirement of the crop is fulfilled by irrigation water. Different terms used in this regard are described below.

Net Irrigation Requirement

Net irrigation requirement is the depth of irrigation water, exclusive of precipitation, carry over soil moisture or ground water contribution or other gains in soil moisture, that is required consumptively for crop production. It is basically the amount of irrigation water required to bring the soil moisture level in the effective root zone to field capacity. This may be give by

$$d = \sum_{i=1}^{n} \frac{(M_{fci} - M_{bi})}{100} \cdot A_i \; D_i$$

where, d = Net amount of irrigation water to be applied (cm),

M_{fci} = Field capacity moisture content in the i^{th} layer of the soil (%),

M_{bi} = Moisture content before irrigation in i^{th} layer (%),

A_i = Bulk density in i^{th} layer (g/cm^3),

D_i = Depth of i^{th} layer (cm), and

n = Number of soil layer in the root zone D.

Gross Irrigation

It is total amount of water applied through irrigation. It is basically net irrigation requirement plus losses in application of water including other loss.

$$\text{Gross irrigation requirement in the field} = \frac{\text{Net irrigation requirement}}{\text{Field efficiency of system}}$$

Example 2.1

The net amount of irrigation required for a field is 6.4 cm, if the field efficiency is 80 %. What is the gross amount of water required to be applied in the field.

Solution

$$\text{Gross irrigation requirement in the field} = \frac{\text{Net irrigation requirement}}{\text{Field efficiency of system}}$$

$$= \frac{64}{0.8} = 8 \text{ cm}$$

Gross requirement of water is 8 cm depth of water over the field.

Gross irrigation Requirement in a Crop Season

It is calculated based on water requirement in one irrigation and number of irrigation in crop season.

$$IR = \sum_{1}^{n} \frac{d}{E_{\text{application}}}$$

where, IR = Seasonal gross irrigation requirement at the field head, cm,

d = Net amount of water applied in each irrigation, cm,

$E_{\text{application}}$ = Water application efficiency, and

n = Number of irrigation in a season.

2.3.2 Frequency of Irrigation

Design Frequency

The design frequency is equal to

$$\frac{\text{(Net irrigation requirement in the effective crop root zone} - \text{Moisture content of the same zone at the time of starting of irrigation)}}{\text{Peak period moistures rate of crop}}$$

Amount of Water to Apply per Irrigation

With 'full irrigation' the amount of water required per irrigation is computed as follows :

$$1 = \frac{D_r\,(f_c - f_m)}{\text{Irrigation efficiency}}$$

in which,

1 = Amount of water to be applied, cm,

D_r = Depth of root zone, cm,

f_c = Soil moisture content at field capacity, and

f_m = Soil moisture content prior to irrigation.

2.3.3 Different Stages of Growth at which Irrigation is Required

Water requirement of crops vary with the stage of its growth. So in case when water supply is limited, understanding of the critical stages of crop growth with respect to moisture is necessary. In fact, critical stage is commonly used to define the stage of growth when plants are most sensitive to water deficit. Each crop has certain critical stages at which if there is moisture deficit, yield is reduced drastically. The *Critical growth stages of cereals in relation to irrigation* is given below including terms used to describe the growth and developmental stages of grain crop in relation to irrigation.

Sl. No.	Stage	Details
1.	Germinatio n	The appearance of the radical
2.	Tillering	The formation of tillers, i.e. branches produced from the base of the stem
3.	Jointing	The stage when 2 nods can be seen, i.e. the beginning of shooting
4.	Shooting	The stage of elongation of internodes
5.	Booting	The end of the shooting stage and just prior to the emergence of ears
6.	Heading (Earing)	The emergence of the ear from the tube formed by the leaf sheaths
7.	Flowering	The period of grain development from fertilisation until maturity
8.	Grain formation	The period of grain development from fertilisation until maturity. This period can be further subdivided into the following : 'milk stage' – grain contents have a milky consistency 'dough stage' – grain contents have a doughy consistency 'waxy-ripe' – grain contents have a waxy appearance 'full-ripe' – grain contents are hard 'dead-ripe' – grain ripe for harvesting

SAQ 1 ?

Discuss the functions of irrigation water and define net and gross irrigation requirement.

2.4 IRRIGATION SCHEDULING

The requirement regarding the number of irrigations and their timings vary widely for different crops. Earlier considered transpiration of the potted plants was the basis of water requirement of crops. But the estimated values obtained under field conditions deferred widely and thus the concept got limited practical utility so far as irrigation scheduling for field crops was concerned. This led to emergence of different concepts of estimation of water requirement which ultimately refined the actual water requirement of crops.

Delta Concept

In this concept arbitrarily chosen *delta* (depth of irrigation in cm) values for different situations and intervals of irrigation were tried for scheduling of irrigations. But delta concept did not take into account the soil moisture status at the time of irrigation and the rainfall received during the irrigation interval.

Soil Water Regime Concept

According to this concept the water content at field capacity (the upper limit of the regime) was considered as 100 per cent available for crop growth and that at the permanent wilting point as 0 per cent available. The safe limit of allowable soil water depletion (the lower limit of the regime) for a crop was determined by experimentation and it was taken as a criterion for scheduling irrigation. This approach worked well under a given soil and climatic conditions. For quick measurement of soil moisture various gadgets like tensiometers, gypsum blocks and neutron moisture meter were used.

Evapotranspiration and Evaporation Concept

As climatic parameters play a predominant role in governing the water needs of crops and the criterion of soil water availability for scheduling of irrigations cannot be considered in isolation from that of climatic factors. This led to the concepts of evapotranspiration and evaporation in which plant was considered simply as an aquaduct pumping water retained in the soil and losing it to the atmosphere under the influence of atmospheric sink. This was, however, not completely true as the plants were also found to have resistances in the absorption of water. When absorption lagged behind transpiration, plants showed temporary wilting and the stomatal openings got closed to overcome the situation. Some physiological stages of growth were found to be more critical in their demand for water than others.

Plant Water Status Concept

The latest approach for scheduling of irrigations is, therefore, the plant water status itself. This may be considered as an ideal criterion as the plant is a good integrator of soil, water and climatic factors. It is, however, not yet in common use due to lack of standard and low cost techniques to measure the plant water status or potential.

Irrigation Scheduling of Major Crops of India

Rice

Rice is a semi-aquatic plant which occupies about 40 per cent of the irrigated area in India and its water requirements are many times more than most other food crops. It is, therefore, a major consumer of the water resources of the country and needs careful water management. It is grown under varied soil and climatic conditions and one to three crops per annum are taken in one or the other part of India. The crop thrives best under conditions of high temperature and humidity. In tropical and sub-tropical conditions, as in southern India, rice can be grown practically throughout the year. In temperate regions and at high altitudes the crop is grown only in the warm season. Rice is grown in two conditions, namely, low land and upland. Upland rice is directly grown by drilling or by broadcasting the seeds and depends mostly on rain. Under low land conditions rice is generally transplanted on puddled soils and land is kept under submerged conditions by rain and/or irrigation water. The practice of puddling and land submergence, reducing the percolation losses in addition to many other benefits. The practice of shallow submergence (about 5 ± 2 cm water) directly save considerable amount of water as compared to deep submergence. It is not always to keep continuous submergence, especially in the kharif season when the humidity is high and evaporation is low submergence during the critical stages of initial tillering and/or flowering and maintenance of saturation to field capacity during the rest of the stages give yields comparable to those obtained under continuous shallow submergence. A special technique for rice cultivation, i.e. the Taiwan practice is basically to produce high crop yields and use water economically by adopting a definite sequence of land submergence and drainage, based on the stage of growth of the rice crop. In this method the schedule of irrigation and drainage is as follows :

(a) The transplanting of the paddy seedlings is done in as shallow water as possible.

(b) From the day of transplanting to 5 to 8 days about 3 to 5 cm of standing water is maintained in the transplanted plots.

(c) From the 7th day of transplanting to about 40th to 45th day a shallow water level is maintained (about 2 to 3 cm deep) in the plots.

(d) During the period of 40th to 50th day after transplanting, the field is drained completely.

(e) Water is kept ponded to a depth of 7 to 10 cm during the period 55 to 70 days (Panicle initiation is during this period).

(f) During the booting stage, between 70 to 80 days, the depth of ponding is only about 3 cm.

(g) From the 80th day till about 90th day, during which period the heading is completed, a water depth of 7 to 10 cm is maintained.

(h) The water is drained completely about 7 days before harvesting (this facilitates the use of mechanical equipment in harvesting).

Wheat

Wheat is grown on an area of about 26.3 million hectares in India and nearly 54 per cent of this area is irrigated, which constitutes about 27 per cent of the irrigated area in the country. The most practical criterion commonly adopted for scheduling of irrigations in wheat is the one based on the physiological growth stages critical in demand for water. In wheat, different growth stages such as crown root initiation, tillering, jointing, boot, flowering, milk and dough could be well delineated. In case of dwarf varieties of wheat irrigation at the crown root initiation (CRI) stage (20-25 days after sowing) gives the maximum production per unit of water applied and, is the most critical stage for irrigation. If the soil zone around the crown is dry at the time of the crown root initiation, crown roots do not develop properly and only a few tillets are produced. The second important stage is that of flowering which takes place at 80-85 days after sowing. Among the other stages, jointing and milk rank third, followed by tillering stage, and then dough stage. Irrigation must be applied at the initiation of the stage so that the moisture in the soil is amply available during a given stage. In case of shortage of water, it is recommended that irrigations may be applied at CRI stage when water for only one irrigation is available and at CRI and flowering stages when water for two irrigations is available.

Maize

It is grown almost all over India under varied soil and c1imatic conditions. It is essentially a warm and humid season crop. A fertile, well-drained loamy soils is best for it. The irrigation requirement of maize vary with the type of soil and the season and depending upon the rainfall received. In the northern India, the crop is normally sown after pre-sowing irrigation. During the monsoon, irrigation may be required whenever soil moisture falls below the desired level. The early vegetative considerably stage (20-40 days after sowing) and tasselling and silking stage (45-60 days after sawing) have been observed as critical stages in terms of demand for water by maize. Maize is very sensitive to excess water and hence it is advisable to plant it on ridges. Submergence of the soil for three to five days during seedling or flowering period reduce the yield.

Sorghum

Sorghum is important crop of relatively dry tract of central and southern India. It grows best in semi-arid areas with well-distributed rainfall of about 300 to 1000 mm. The temperature in the growing season should be within the range of 16 to 40°C. Sorghum is grown on, a variety of soils ranging from clay to sandy loams. When grown on clay-to-clay loams the irrigation requirement is low and on lighter soils, irrigation requirement is higher. Initial seedling, pre-flowering, flowering, and grain formation stages coinciding with 2-4, 12-14, 14-16 and 17 weeks after sowing, respectively. These stages have been found critical for water demand of sorghum.

Pearl Millet

Pearl millet *(bajra)* is well suited to warm areas of low rainfall (200-500 mm). *Bajra* is preferred when the rainfall is inadequate for maize and sorghum as it is more tolerant to drought. However, *bajra* responds well to the application of supplemental irrigations. The irrigation requirements of *bajra* when grown in the kharif season vary from 150 to 200 mm in most parts of the country. It has been proved that *bajra* tolerates about 75 per cent depletion of available moisture from 0-30 cm depth of soil on heavy clay soils. On sandy loam soils, however, best yields are obtained with irrigations at 50 per cent depletion level.

Barley

It is grown as a rainfed crop in areas having rainfall of 400-500 mm in the growing season and needs less water than wheat or oats for its growth. In drier areas the crop needs irrigation for good growth. The moisture sensitive period occurs at the end of the shooting stage and during earing when the generative organs are being formed. During this period drought conditions have maximum effect in reducing yield in other words irrigations have the greatest effect in increasing yield. During this period excess water has very little adverse effect on yield.

Finger Millet

Finger millet, commonly known as *ragi,* is one of the important grain crops of southern India. In the heavy black clay soils and sandy loam soils, irrigation given at 50 per cent available moisture depletion upto the top 30 cm soil layer becomes necessary to obtain higher yields of *ragi* sown in the summer season while that sown in the *kharif* season did not require any irrigation.

Pulses

Pulses, by virtue of their deep tap root system, utilize soil moisture very efficiently and hence, require less number of irrigations as compared to cereals. These crops, therefore, find a place in the cropping pattern in areas with limited water resources. Legumes in *kharif* season are normally grown without any irrigation in most parts of India, unless the rainfall distribution is very unfavourable. Legumes grown in *rabi* and summer season, however, depend on irrigation. Most of the legumes do not require irrigation at the early vegetative stage as it may do more harm than good by interfering with the nodulation and oxygen requirement of roots at this stage. These crops derive maximum benefits from irrigation during flowering and podding stages.

Gram

Gram also known as chickpea or *chana*, is extensively grown in northern India in the *rabi* season on alluvial sandy loam to loam soils however, in central and southern India the crop is grown on water retentive clay loam soils and hence is not normally irrigated. The crop is best suited to low rainfall areas. However, it has been found to respond to irrigation in the absence of winter rains especially on the lighter soils of northern India. This crop generally requires only one or two irrigations when grown in *rabi* in northern India. Pre-flowering (45 days after sowing) and flowering (70 days after sowing) stages have been found to be critical w.r.t. irrigation.

Pegion Pea

Pigeon pea commonly known as red gram (*arhar*), is grown all over India. The crop can be grown on almost all types of soils, ranging from alluvial sandy loam to heavy black clay soils. The crop benefits from irrigation if dry spells prevail for longer periods. Flower initiation (about 75 days after sowing) and pod filling (about 100 days after sowing) are found to be most responsive to irrigation for short duration red gram.

Green Gram

Green gram is cultivated all over the country. It is largely grown as a rainfed *kharif* crop. In *rabi* and summer the crop reqyires two to four irrigations for high yields. A pre-sowing irrigation is generally found to be beneficial.

Oilseeds

Oil seeds occupy approximately 25 per cent of the total cropped area of India. Like grain legumes, oilseeds are also efficient in water use and hence require less water for their growth. Irrigation requirement is mainly based on soil moisture depletion levels, depending the rainfall during the growing season. Irrigation at 50 per cent available moisture level is found to produce high yields. Flowering and fruiting stages are observed to be most responsive to irrigation.

Mustard and Rapeseed

These are crops of tropical as well as temperate zones and require cool weather for satisfactory growth. Pre-flowering (about 40 days after sowing) and pod filling (about 80 days after sowing) stages have been observed to be the most responsive to irrigation.

Sunflower

Sunflower crop is photo insensitive and can be grown in any season. It takes three to four months for its maturity. The requirement of irrigation depends on the availability of rains during the growing season. Maintenance of a soil moisture level of 50 per cent in the effective root zone has been found to give the best yields.

Safflower

It is drought resistant but has been found to respond to irrigation, especially on sandy loam sails. Flowering and ranching stages (about 105 and 65 days; respectively after sowing) are found to be critical in water requirements. The crop usually does not respond significantly to more than two irrigations in most cases.

Fibre Crops

Cotton

Cotton is a sub-tropical crop grown in areas with 750 to 2500 mm rainfall. It can extract most of the soil moisture to the depth of rooting and this characteristic has an important influence on irrigation requirement. Sufficient water should be added to the soil, either from rainfall or irrigation, to ensure that the entire root zone is brought to field capacity early in the growing season, i.e. within 40 days after planting. Pre-flowering stage irrigation may be needed if there is little or no rain fall. It is desirable to maintain availability soil moisture so that it does not fall below the level of 50 per cent of availability in the upper 45 to 75 cm. Normally, it is desirable to allow the cotton crop to mature on stored soil moisture, and extract almost all available soil moisture at the end of the season.

Jute

Jute is an important fibre crop of India. Irrigation schedules based on the maintenance of a soil moisture deficiency level of 50 to 60 per cent have been observed to be most favourable for jute.

Sugarcane

Sugarcane is a tropical crop and requires warm humid climate for its good growth. Sugarcane has an extensive fibrous root system, with roots most extensive in the upper 60 to 90 cm of soil and in certain cases it may extend to depths as much as 240 cm in well-drained, deep loamy soils. Moisture extraction is greater in the upper 120 cm. Rooting patterns will vary with soil type and drainage conditions. Optimum yields of sugarcane are obtained by maintaining a very high moisture level throughout the root zone, during the entire growing season, until about one month before harvest. Irrigation should be scheduled by observing soil moisture content. Average soil moisture in the first 60 cm should generally be kept at a level of above 66 per cent of total available moisture.

Vegetables

One or the other vegetable crop is grown at any time of the year, depending upon the availability of irrigation water. The irrigation requirement of vegetable crop varies depending upon the duration of the crop and the season of cultivation. It is essential to schedule irrigations of vegetables to maintain a continuous high soil moisture level in the soil. Irrigation should be scheduled by observing soil moisture level, not by observation of the crop.

Forage Crops

As a general rule, optimum forage production is possible only with a continuous high moisture level. A safe rule to follow is to irrigate so as to keep the available soil moisture level above 50 percent at all times,

Spices and Condiments

Important crops in this group are turmeric, ginger, cardamom, cumin, coriander. Coriander and cumin are winter crops need irrigation at intervals of 10 to 12 days on light soils and 15 to 20 days on heavy *soil.* The water requirements of these crops are around 500 to 600 mm.

2.5 IRRIGATION EFFICIENCIES

Efficiency is the ratio of the water output to the water input, and is usually expressed as percentage. Input minus output is nothing but losses, and hence, if losses are more, output is less and, therefore, efficiency is less. Hence, efficiency is inversely proportional to the losses. Water is lost in irrigation during various processes and, therefore, there are different kinds of irrigation efficiencies, as given below.

Efficiency of Water-conveyance

It is the ratio of the water delivered into the fields from the outlet point of the channel, to the water entering into the channel at its starting point. It may be represented by η_c. It takes the conveyance or transit losses into consideration.

$$\eta_c = \frac{Wf}{Wd} \times 100$$

where, η_c = Water conveyance efficiency,

Wf = Water delivered to the irrigated plot at field supply channel, and

Wd = Water diverted from the source.

Efficiency of Water Application

It is ratio of water stored in root zone to the water delivered at the field. It may be represented by η_a.

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

where, η_a = Water application efficiency,

Ws = Water stored at the root zone of plant, and

Wf = Water delivered to the field at the field supply channel.

Efficiency of Water-storage

It is the ratio of the water stored in the root zone during irrigation to the water needed in the root zone prior to irrigation (i.e. field capacity – existing moisture content). It may be represented by η_s.

$$\eta_c = \frac{Ws}{Wn} \times 100$$

where, η_s = Water-storage efficiency,

Ws = Water stored at the root zone of plant, and

Wn = Water needed in the root zone prior to irrigation.

Efficiency of Water Use

It is the ratio of the water beneficially used, including leaching water, to the quantity of water delivered. It may be represented by η_u.

$$\eta_u = \frac{Wu}{Wd}$$

where , η_u = Water use efficiency,

Wu = Beneficial use of water including leaching water, and

Wd = Water delivered to the field.

It is also expressed as ratio of crop yield to the amount of water depleted by crop in the process of evapotranspiration

$$\text{Crop water use efficiency} = \frac{Y}{ET}$$

where, Y = Crop yield, and

ET = The amount of water depleted by crop in the process of evapotranspiration.

Uniformity Coefficient or Water Distribution Efficiency

The effectiveness of irrigation may also be measured by its water distribution efficiency (η_d), which is defined below :

$$\eta_d = \left(1 - \frac{d}{D}\right)$$

where, η_d = Water distribution efficiency,

D = Mean depth of water stored during irrigation, and

d = Average of the absolute values of deviations from the mean.

The water distribution efficiency represents the extent to which the water has penetrated to a uniform depth, throughout the field. When the water has penetrated uniformly throughout the field, the deviation from the mean depth is zero and water distribution efficiency is 1.0.

Example 2.2

An area of 10 hectares is to be irrigated by a pump working for 12 hours a day. The available moisture holding capacity of the soil is 16 cm/m and the depth of root zone is 1m. Irrigation is to be done when 50 per cent of available moisture in the root zone is depleted. Water application efficiency is 70 per cent. Peak rate of moisture use by the crop is 4 mm (weighted average). Losses in water conveyance are negligible. Determine the irrigation period, net depth of water application, depth of water pumped per application, and the require capacity of the irrigation system in hectare-cm/day and liters per second.

Solution

Net depth of water application $= 16 \times \frac{50}{100} = 8$ cm

Irrigation period $= \frac{\text{Net irrigation requirement}}{\text{Peak use rate}} = \frac{8}{0.4} = 20$ days

Depth of water pumped per application $= \frac{8}{0.7} = 11.4$ cm

Required capacity of irrigation system

$$= \frac{11.4 \text{ cm} \times 20 \text{ ha}}{20 \text{ days}} = 11.4 \text{ hectare-cm/day}$$

$$= \frac{11.4 \times 10000 \times 1000}{100 \times 12 \times 60 \times 60} = 26.4 \text{ litres per second}$$

Example 2.3

A stream of 135 liters per second was delivered from a canal and 100 liters per second were delivered to the field. An area of 1.6 hectares was irrigated in 8 hours. The effective depth of root zone was 1.8 m. The runoff loss in the field was 432 cu m. the depth of water penetration varied linearly from 1.8m at the head end of the field to the 1.2 m at the end of the tail end. Available moisture holding capacity of the soil is 20 cm per meter depth of soil. Determine the water conveyance efficiency, water application efficiency, water storage efficiency and water distribution efficiency; irrigation was started at a moisture extraction level of 50 per cent of the available moisture.

Solution

Efficiency of water-conveyance, $\eta_c = \frac{Wf}{Wd} \times 100$

$$= \frac{100}{135} \times 100 = 74\%$$

Water application efficiency, $\eta_a = \frac{Ws}{Wf} \times 100$

Water delivered to the plot $= \frac{100 \times 60 \times 60 \times 8}{100} = 2800$ cu. m

Water stored in the root zone = 2880 – 432 = 2448 cu. m

Water application efficiency, $\eta_a = \dfrac{2448}{2880} \times 100 = 85\%$

Water storage efficiency, $\eta_s = \dfrac{Ws}{Wn} \times 100$

Water holding capacity of the root zone = 20 × 1.8 = 36 cm

Moisture required in the root zone $= 36 - \dfrac{36 \times 50}{100} = 18$ cu. m

$$= \frac{18}{100} \times 1.6 \times 10000 = 2880 \text{ cu. m}$$

Water storage efficiency, $\eta_s = \dfrac{2448}{2880} \times 100 = 85\%$

Water distribution efficiency, $\eta_d = \left(1 - \dfrac{d}{D}\right) \times 100$

$$D = \frac{1.8 + 1.2}{2} = 1.5 \text{ m}$$

Numerical deviation from depth of penetration :

At upper end = 1.8 – 1.5 = 0.3

At lower end = 1.5 – 1.2 = 0.3

Average numerical deviation, $= \dfrac{0.3 + 0.3}{2} = 0.3$

Water distribution efficiency, $\eta_d = \left(1 - \dfrac{0.3}{1.5}\right) \times 100 = 80\%$.

SAQ 2

(a) Discuss irrigation scheduling of Rice, Wheat, Pulses and Sugarcane in detail.

(b) Define different kind of irrigation efficiencies and their practical significance.

(c) 10 cumecs of water is delivered to a 30 hectare field for 5 hours. Soil probing after the irrigation indicates that 0.5 metre of water has been stored in the root zone. Estimate the water application efficiency.

2.6 TERMS USED IN WATER PLANNING

Delta

Delta is the total depth of water required by a crop during the entire period of crop in the field, and is denoted by a symbol Δ.

For Example, if a crop requires, about 11 watering at an interval of 10 days and a water depth of 10 cm is applied in every watering, then the delta for that crop will be 11 × 10 = 110 cm = 1.10 meters.

Base Period

It is the time in days counted from the period of first watering for a crop before sowing the crop (known as presowing irrigation) and the last watering before harvesting the crop. Normally the base periods are given for different agro ecological zones. For example base period in Maharastra state is given as below :

Kharif crop – 123 days and Rabi – 120 days.

It is different from the crop period as Crop period is the time in days that the crop takes from the instant of its sowing to that of its harvest.

Duty

Duty is defined as the area irrigated by a unit discharge during the Base period of crop or in other words Duty may be defined as the area irrigated by an average discharge of 1 cumec for a specified number of days.

For example, if 4 cumecs of water supply is required for a crop sown in an area of 5000 hectares, the duty of irrigation water will be $\frac{5000}{4} = 1250$ hectares/cumec, and the discharge of one cumec will be required throughout the Base period.

The importance of duty is that it helps in designing an efficient irrigation canal system. The area to be irrigated can be found out if we know the following factor :

(a) Total available water at the head or main canal.

(b) Overall duty for all the crops required to be irrigated in different seasons of year.

Duty also helps for checking the efficiency of canal system.

Average Duty

It is the flow duty computed at the head (beginning) of a distributary or for main canal of small projects. The average duty is always less than the duty. In average duty the Transit losses has to be taken into account.

Gross Duty or Tank Duty

This duty is useful in water planning. Gross duty may be defined as area under varieties of crops irrigated by one million cubic meters of water stored in the Tank, in one year.

Relation between Duty and Delta

Let D = Duty in hectares/cumec,

Δ = Total depth of water (in meters), and

B = Base period in days.

(a) If we take a field of area D hectares; water supplied to the field corresponding to the water depth Δ meters will be

$$= \Delta \times D \text{ hectares meters} = D \times \Delta \times 10^4 \text{ cubic meters} \quad \ldots (1)$$

(b) Again for the same field of D hectares, one cumec of water is required to flow during the entire base period. Hence, water supplied to this field

$$= 1 \times (B \times 24 \times 60 \times 60)\ m^3 \qquad \ldots (2)$$

Equating Eqs. (1) and (2) we get,

$$D \times \Delta \times 10^4 = B \times 24 \times 60 \times 60$$

$$\Delta = 8.64\ B/D \text{ meters.}$$

Example 2.4

If the rice requires about 12 cm depth of water at an interval of 10 days and base period for rice is 120 days, find out the delta for rice.

Solution

Water required at an interval of 10 days for a period of 120 days. It means that 12 numbers of watering are required and each time 12 cm depth of water is required.

Total depth of water = 12 cm × 12

$$\Delta = 144 \text{ cm}$$

Example 2.5

Calculate the delta for kharif jawar having duty as 2600 ha/cumec.

Solution

Using the equations :

$$\Delta = 8.64 \times \frac{B}{D}, \text{ Base period for kharif} = 123 \text{ days}$$

$$= 8.64 \times \frac{123}{2600}$$

$$= 40.87 \text{ cm}$$

Example 2.6

In an experiment station on paddy growth, it was observed that in 98 days in kharif, the depth of water supplied was 120 cm. Calculate the duty.

Solution

The 98 days is actual base period, however for calculation of duty, standard base period is to be taken.

Therefore, 98 days has no bearing on the solution.

For kharif base period = 123 days

$$\Delta = 120 \text{ cm} = 1.2 \text{ m}$$

$$D = 8.64 \times \frac{123}{1.2}$$

$$= 885.6 \text{ ha/cumec}$$

Example 2.7

Find out the capacity of the reservoir if its culturable area is 65000 ha, from the following data :

Sl. No.	Type of crop	Sugarcane	Wheat	Rice
1.	B in days	330	120	120
2.	D in ha/cumec	2200	1800	800
3.	Intensity of irrigation as percentage	15	20	10

Solution

$$\text{Delta (Sugarcane)} = 8.64 \times \frac{330}{2200} = 1.29 \text{ m}$$

$$\text{Delta (Wheat)} = 8.64 \times \frac{120}{1800} = 0.576 \text{ m}$$

$$\text{Delta (Rice)} = 8.64 \times \frac{120}{800} = 1.296 \text{ m}$$

$$\text{Area under sugarcane} = 65000 \times \frac{15}{100} = 9750 \text{ ha}$$

$$\text{Area under wheat} = 6500 \times \frac{20}{100} = 13000 \text{ ha}$$

$$\text{Area under rice} = 6500 \times \frac{10}{100} = 6500 \text{ ha}$$

Quantity of water for,

Sugarcane = 9750 × 1.296 = 12636 ha meter

Wheat = 13000 × 0.576 = 7488 ha meter

Rice = 6500 × 1.296 = 8424 ha meter

Total quantity of water required = 12636 + 7488 + 8424 = 28548 ha meter

Total loss = 16 %

$$= 28548 \times \frac{16}{100} = 4567.68 \text{ ha meter}$$

The capacity of the reservoir = 28548 + 4567.68

= 33115.68 ha meter

Command Area

"The area which lies on down stream side of project to which water can reach by gravity action." There are the three types of commanded areas.

Gross Commanded Area (G.C.A)

The Gross commanded area is the total area lying between drainage boundaries which can be irrigated by a canal system.

Cultivable Commanded Area (C.C.A)

It is the net area, which can be irrigated by a canal system. It includes all land on which cultivation is possible, though all area may not be under cultivation at the time.

$$G.C.A. = C.C.A. + \text{Uncultivable area}$$

Irrigable Commanded Area (I.C.A)

It is the part of cultivable commanded area, which can be irrigated. All the C.C.A. cannot be irrigated because of high elevation.

Intensity of Irrigation

It is the ratio of area irrigated per season to total irrigable areas or small projects is based on this.

SAQ 3 **?**

(a) Establish the relation between duty and delta.

(b) The left branch canal carrying a discharge of 25 m^3/sec has CCA of 25,000 hectares. The intensity of Rabi crop is 80% and the base period is 118 days. The right branch canal carrying discharge of 10 m^3/sec has CCA of 15000 hectare, intensity of irrigation of Rabi crop is 60% and base period is 118 days. Compare the efficiencies of the two canal system.

2.7 SUMMARY

This unit discusses the water requirement of different crops, irrigation scheduling, irrigation efficiencies and various terms such as delta, duty, base period, GCA, CCA, etc. The irrigation scheduling of major crops in India such as rice, wheat, pulses, gram, etc. are explained in detail. The estimation of capacity of irrigation system is also discussed.

2.8 KEY WORDS

Delta : It is the total depth of water required by a crop during the entire period of crop in the field and denoted by Δ.

Duty : It is the area irrigated by a unit discharge during the base period of crop and denoted by D.

Efficiency : It is the ratio of water output to the water input and is usually expressed as percentage.

2.9 ANSWERS TO SAQs

SAQ 1

Refer Section 2.3.1.

SAQ 2

(a) Refer Section 2.4.

(b) Refer Section 2.5.

(c) Volume of water supplied in 5 hours

$= 10 \times 5 \times 60 \times 60 = 180000 \text{ m}^3 = 18$ ha-m

Hence, Input = 18 ha-m

Output = 30 ha land is storing water upto 0.5 m depth

$= 30 \times 0.5 = 15$ ha-m

$$\text{Water application efficiency} = \frac{15}{18} \times 100 = 83.3\%$$

SAQ 3

(a) Refer Section 2.6.

(b) For left canal

Area $= 25000 \times 0.8 = 20000$ hectare

Discharge $= 25 \text{ m}^3/\text{sec}$

$$\text{Duty} = \frac{20000}{25} = 800 \text{ hectare/cumecs}$$

For right canal

Area $= 15000 \times 0.6 = 9000$ hectare

Discharge $= 10 \text{ m}^3/\text{sec}$

$$\text{Duty} = \frac{9000}{10} = 900 \text{ hectare/cumecs}$$

Hence, right canal system is more efficient as it has higher duty.