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FACULTY OF AGRICULTURAL SCIENCES & ALLIED INDUSTRIES

Water use efficiency, irrigation-scheduling criteria and methods, quality of irrigation water

Water use efficiency

It is the ratio of the quantity of dry matter produced to the total depth of water consumed during the entire crop growth season and is expressed as kg per cm.

An efficient irrigation system implies effective transfer of water from the source to the filed 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 a measure of efficiency of water conveyance system from canal network to watercourses and field channels. It is the ratio of water delivered infields at the outlet head to that diverted into the canal system from the river or reservoir. Water losses occur in conveyance from the point of diversion till it reaches the farmer's fields which can be evaluated by water conveyance efficiency, as under:

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

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 a measure of efficiency of water application in the field. It is the ratio of volume of water that is stored in the root zone of crops and ultimately consumed by transpiration or evaporation or both to the volume of water actually delivered at the field. Alternatively, it may be defined as the percentage of water applied that can be accounted for as increase in soil moisture in soils as occupied by the principal rooting system of the crop. It is also termed as farm efficiency as it takes into account water lost in application at the farm. We have

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

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)

In general, water application efficiency decreases as the amount of water during each irrigation increases. Water losses due to inefficient application of water in the field vary from 28 to 50 %.

Common sources of loss of irrigation water during application are represented thus:

Rf = surface runoff from the farm

Df = deep percolation below the farm root zone soil

Neglecting evaporation losses during application, we have

$$Wf = Ws + Df + Rf$$

$$Ec = Wf - \frac{(Df + Rf)}{Wf} \times 100$$

4. Water Use Efficiency

Having conveyed water to the point of use and having applied it, the next efficiency concept of concern is the efficiency of water use. It is expressed in kg/ha cm. The proportion of water delivered and beneficially used on the project can be calculated using the following formula

$$Eu = \frac{Wu}{Wd} \times 100$$

where,

Eu = water use efficiency, per cent

Wu = water beneficially used

Wd = water delivered

Water use efficiency is also defined 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 evapotranspiration (ET).

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

where,

CWUE = Crop water use efficiency

Y = Crop yield

ET = Evapotranspiration

CWUE is otherwise called consumptive water use efficiency. It is the ratio of crop yield (Y) to the sum of the amount of water taken up and used for crop growth (G), evaporated directly from the soil surface (E) and transpired through foliage (T) or consumptive use (Cu)

$$CWUE = \frac{Y}{G + E + T}$$

where,

$$(G + E + T) = Cu$$

In other words ET is Cu since water used for crop growth is negligible.

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

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.

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

where,

FWUE = field water use efficiency

WR = water requirement

This is the ratio of crop yield to the amount of water used in the field (WR) including growth (G), direct evaporation from the soil surface (E), transpiration (T) and deep percolation loss (D).

$$FWUE = \frac{Y}{G + E + T + D}$$

$$G + E + T + D = WR$$

It is expressed in kg/ha/mm (or) kg/ha/cm

Deep percolation is important for rice crop. For other crops seepage is important. Of the two indices defined, the crop water use efficiency is more of research value whereas the field water use efficiency has grater practical importance for planners and farmers.

5. **Water Storage Efficiency:**

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

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

where,

E_s = water storage efficiency, per cent

W_s = water stored in the root zone during the irrigation

W_w = water needed in the root zone prior to irrigation, i.e., field capacity

6. **Water Distribution Efficiency**

Expression for distribution efficiency to evaluate the extent to which the water is uniformly distributed is as follows:

$$E_d = \frac{(1-d)}{D} \times 100$$

$$= \frac{(1- \text{average deviation})}{\text{Average depth applied}} \times 100$$

where,

E_d = water distribution efficiency, per cent

d = 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.

7. **Consumptive Use Efficiency**

It is defined as the ratio of consumptive water use by the crop of irrigated farm or project and the irrigation water stored in the root zone of the soil on the farm or the project area. 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

Consumptive use efficiency is useful in explaining the difference in crop response from different methods of irrigation.

Irrigation- scheduling criteria and methods

Irrigation scheduling is defined as frequency with which water is to be applied based on needs of the crop and nature of the soil.

Irrigation scheduling is nothing but number of irrigations and their frequency required to meet the crop water requirement.

Irrigation scheduling may be defined as scientific management techniques of allocating irrigation water based on the individual crop water requirement (ETc) under different soil and climatic condition, with an aim to achieve maximum crop production per unit of water applied over a unit area in unit time.

Based on the above definition, the concept made is.

"If we provide irrigation facility the agricultural production and productivity will go up automatically"

Irrigation scheduling is a decision making process repeated many times in each year involving when to irrigate and how much of water to apply? Both criteria influence the quantity and quality of the crop. It indicates how much of irrigation water to be used and how often it has to be given.

Effect of application of right amount and excess amount of water Excess irrigation is harmful because

a) It wastes water below root zone

b) It results in loss of fertilizer nutrients

c) It causes water stagnation and salinity

d) It causes poor aeration

e) Ultimately it damages the crops

However, Irrigation scheduling has its own meaning and importance according to the nature of the work.

For irrigation Engineers

Irrigation scheduling is important to cover more area with available quantity of water or to satisfy the whole command from head to tail reach in the canal or river system.

For soil scientists

It is important that the field should not be over irrigated or under irrigated as both will spoil the chemical and physical equilibrium of the soil.

For Agronomists

It is very much important to get higher yield per unit quantity of water in normal situations and to protect the crop to get as much as possible yield under drought situation by means on supplying water in optimum ratio and minimizing all field losses.

Importance of irrigation scheduling

How much and how often water has to be given depends on the irrigation requirement of the crop.

Irrigation requirement (IR) = Crop water requirement (CWR) – Effective rainfall (ERF)

It can be expressed either in mm/day/ or mm/month

If the crop water requirement of a particular crop is 6 mm per day, it means every day we have to give 6 mm of water to the crop. Practically it is not possible since it is time consuming and laborious. Hence, it is necessary to schedule the water supply by means of some time intervals and quantity. For example the water requirement of 6 mm/ day can be scheduled as 24 mm/for every 4 days or 30 mm/for every 5 days or 36 mm/for every 6 days depending upon the soil type and climatic conditions prevailing in that particular place. While doing so we must be very cautions that the interval should not allow the crop to suffer for want of water.

a. It enables the farmer to schedule water rotation among the various fields to minimize crop water stress and maximize yields.
b. It reduces the farmers' cost of water and labour
c. It lowers fertilizer costs by holding surface runoff
d. It increases net returns by increasing crop yields and crop quantity

Practical considerations in irrigation scheduling

Before scheduling irrigation in a farm or field or a command, the following criteria should be taken care for efficient scheduling

1. **Crop factors**
   a) Sensitiveness to water shortage
   b) Critical stages of the crop
   c) Rooting depth
   d) Economic value of the crop
2. **Water delivery system**
   a) Canal irrigation or tank irrigation (It is a public distribution system where scheduling is arranged based on the decision made by public based on the resource availability).
   b) Well irrigation (individual decision is final)
3. **Types of soil**
   a) Sandy – needs short frequency of irrigation and less quantity of water
   b) Clay – needs long frequency of irrigation and more quantity of water
4. **Salinity hazard**
   To maintain favorable salt balance, excess water application may be required rather than ET requirement of the crop to leach the excess salt through deep percolation
5. **Irrigation methods**
   a) Basin method allows more infiltration through more wetting surface which in turn needs more water and long interval in irrigation frequency
   b) Furrow method allows less infiltration due to less wetting surface which needs less water and short interval in irrigation frequency.
   c) Sprinkler method needs less water and more frequency d) Drip method needs less water and more frequency

6. **Irrigation interval**

   The extension of irrigation interval does not always save water. The interval has to be optimized based on the agroclimatic situation.

7. **Minimum spreadable depth**

We cannot reduce the depth based on the water requirement of the crop alone. The depth should be fixed based on the soil type, rooting nature of the crop and irrigation method followed. The minimum depth should be so as to achieve uniformity of application and to get uniform distribution over the entire field.

Scheduling irrigation methods

1. **Soil water regime approach**

   In this approach the available soil water held between field capacity and permanent wilting point in the effective crop root zone.

   Alternatively soil moisture tension, the force with which the water is held around the soil particles is also sometimes used as a guide for timing irrigations.

2. **Climatological approach**

   The potential rate of water loss from a crop is primarily a function of evaporative demand of the atmosphere. In this method, the water loss expressed in terms of either potential evapotranspiration (PET).

3. **Plant indices approach**

- Visual plant symptoms
- In this method the visual signs of plants are used as an index for scheduling irrigations.
- For instance, plant wilting, drooping, curling, and rolling of leaves in maize is used as indicators for scheduling irrigation.
- Change in foliage color and leaf angle is used to time irrigations in beans.
- Shortening of internodes in sugarcane and cotton; retardation of stem elongation in grapes.

4. System as a whole approach

A) Rotational water supply

R.W.S is one of the techniques in irrigation water distribution management. It aims at equi-distribution of irrigation water irrespective of location of the land in the command area by enforcing irrigation time schedules.

Each 10 ha block is divided into 3 to 4 sub units (irrigation groups) According to the availability of irrigation water, stabilized field channels and group-wise irrigation requirement, time schedules are evolved. The irrigation will be done strictly in accordance with the group-wise time schedules by the block committees. Within the group, the time is to be shared by the farmers themselves.

Methods of Irrigation

Irrigation

Irrigation is defined as the artificial application of water to the soil for the purpose of crop production in supplement to rainfall and ground water contribution.

Importance of water to plants

1. Plants contain 90% water which gives turgidity and keeps them erect
2. Water is an essential part of protoplasm
3. It regulates the temperature of the plant system
4. It is essential to meet the transpiration requirements
5. It serves as a medium for dissolving the nutrients present in the soil
6. It is an important ingredient in photosynthesis

Criteria for selection of irrigation method

- Water supply source
- Topography
- Quantity of water to be applied
- The crop
- Method of cultivation

Water application methods are grouped as:

1. Flooding
2. Applying it beneath the soil surface
3. Spraying it under pressure
4. Applying in drops

Irrigation methods

I. Surface

II. II. Sub-surface

III. III. Pressurized irrigation

Surface is grouped as Border, Check basin and Furrow irrigations. Border is again classified in to two as straight and contour. Check basins may be of rectangular, contour or ring, whereas furrow irrigation is classified as deep furrow and corrugated furrows. These may be again straight or contour according to direction and leveled and graded as per their elevation

I. Surface irrigation

1. Border irrigation

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.

Suitability :

To soils having moderately low to moderately high infiltration rates. It is not used in coarse sandy soils that have very high infiltration rates and also in heavy soils having very low infiltration rate. Suitable to irrigate all close growing crops like wheat, barley, fodder crops and legumes and not suitable for rice.

Advantages

1. Border ridges can be constructed with simple farm implements like bullock drawn "A" frame ridger or bund former.

2. Labour requirement in irrigation is reduced as compared to conventional check basin method. 3. Uniform distribution of water and high water application efficiencies are possible.

4. Large irrigation streams can be efficiently used.

5. Adequate surface drainage is provided if outlets are available.

2. Check basin irrigation

It is the most common method.

- Here 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 10m2 to 25 m2 depending upon soil type , topography, stream size and crop.

Adaptability

-Small gentle and uniform land slopes

- Soils having moderate to slow infiltration rates.

- Adapted to grain and fodder crops in heavy soils.

- Suitable to permeable soils.

Advantages

1. Check basins are useful when leaching is required to remove salts from the soil profile.

2. Rainfall can be conserved and soil erosion is reduced by retaining large part of rain

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.

Furrow irrigation

⇒ Used in the irrigation of row crops.

⇒ The furrows are formed between crop rows.

⇒ The dimension of furrows depend on the crop grown, equipment used and soil type.

⇒ Water is applied by small running streams in furrows between the crop rows.

⇒ Water infiltrates into soil and spreads laterally to wet the area between the furrows.

⇒ In heavy soils furrows can be used to dispose the excess water.

Adaptability

1. Wide spaced row crops including vegetables.

2. Suitable for maize, sorghum, sugarcane, cotton, tobacco, groundnut, potatoes

3. Suitable to most soils except sand.

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.

Types of furrow irrigation

- Based on alignment of furrows :

1. Straight furrows

2. Contour furrows

- Based on size and spacing :

1. Deep furrows

2. Corrugations

- Based on irrigation:

A. All furrow irrigation:

Water is applied evenly in all the furrows and are called furrow system or uniform furrow system.

B. Alternate furrow irrigation:

It is not an irrigation layout but a technique for water saving. Water is applied in alternate furrows for eg. During first irrigation if the even numbers of furrows are irrigated, during next irrigation, the odd number of furrows will be irrigated.

C. Skip furrow irrigation:

They are normally adopted during the period of water scarcity and to accommodate intercrops. In the skip furrow irrigation, a set of furrows are completely skipped out from irrigation permanently. The skipped furrow will be utilized for raising intercrop. The system ensures water saving of 30-35 per cent. By this method, the available water is economically used without much field reduction.

D. Surge irrigation:

Surge irrigation is the application of water in to the furrows intermittently in a series of relatively short ON and OFF times of irrigation cycle. It has been found that intermittent application of water reduces the infiltration tare over surges thereby the water front advances quickly. Hence, reduced net irrigation water requirement. This also results in more uniform soil moisture distribution and storage in the crop root zone compared to continuous flow. The irrigation efficiency is in between 85 and 90%.

II. Sub-surface irrigation

♦ In subsurface irrigation, water is applied beneath the ground by creating and maintaining an artificial water table at some depth, usually 30-75 cm below the ground surface.

♦ Moisture moves upwards towards the land surface through capillary action

♦ Water is applied through underground field trenches laid 15-30 m apart.

♦ 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.

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
3. Possibility of choking of the pipes lay underground.
4. High cost.

DRIP IRRIGATION SYSTEM

Drip or trickle irrigation is one of the latest methods of irrigation.

- 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

♦ A drip irrigation system consists of a pump or overhead tank, main line, sub-mains, laterals and emitters.

♦ The mainline delivers water to the sub-mains and the sub-mains into the laterals.

♦ The emitters which are attached to the laterals distribute water for irrigation.

♦ The mains, sub-mains and laterals are usually made of black PVC (poly vinyl chloride) tubing. The emitters are also made of PVC material

♦ The other components include regulator, filters, valves, water meter, fertilizer application components, etc.,

Pump

The pump creates the pressure necessary to force water through the components of the system including the fertilizer tank, filter unit, mainline, lateral and the emitters and drippers. Centrifugal pump operated by engines or electric motors are commonly used. The laterals may be designed to operate under pressures as low as 0.15 to 0.2 kg/ cm2 and as large as 1 to 1.75 kg/cm2. The water coming out of the emitters is almost at atmospheric pressure.

Chemical tank

A tank may be provided at the head of the drip irrigation systems for applying fertilizers, herbicides and other chemicals in solution directly to the field along with irrigation water.

Filter

It is an essential part of drip irrigation system. It prevents the blockage of pipes and drippers/emitters. The filter system consists of valves and a pressure gauge for regulation and control.

Emitters

Drip nozzles commonly called drippers or emitters are provided at regular intervals on the laterals. They allow water to emit at very low rates usually in trickles. The amount of water dripping out of each emitters in a unit time will depend mainly upon the pressure and size of the opening. The discharge rate of emitters usually ranges from 2 to 10 litres per hour.

Micro-tubes are also used in a drip lateral. They are used mainly in the following ways (1) as emitters

(2) as connectors,

(3) as pressure regulators

Advantages

1. Water saving - losses due to deep percolation, surface runoff and transmission are avoided. Evaporation losses occurring in sprinkler irrigation do not occur in drip irrigation.
2. Uniform water distribution
3. Application rates can be adjusted by using different size of drippers
4. Suitable for wide spaced row crops, particularly coconut and other horticultural tree crops
5. Soil erosion is reduced
6. Better weed control
7. Land saving
8. Less labour cost

Disadvantages

1. High initial cost
2. Drippers are susceptible to blockage
3. Interferes with farm operations and movement of implements and machineries
4. Frequent maintenance
5. Trees grown may develop shallow confined root zones resulting in poor anchorage.

Layout of sprinkler irrigation system

- The sprinkler (overhead or pressure) irrigation system conveys water to the field through pipes (aluminium or PVC) under pressure with a system of nozzles.

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.

A sprinkler system usually consists of the following parts.

1. A pumping unit
2. Debris removal equipment
3. Pressure gauge / water-meter
4. Pipelines (mains – sub-mains and laterals)
5. Couplers
6. Raiser pipes
7. Sprinklers
8. Other accessories such as valves, bends, plugs, etc.

Pumping unit

A high speed centrifugal or turbine pump can be installed for operating the system for individual farm holdings. The pumping plants usually consist of a centrifugal or a turbine type pump, a driving unit, a suction line and a foot valve.

Pipe lines

Pipelines are generally of two types. They are main and lateral. 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. 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.

Couplers

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

Sprinklers

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.

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.

Types of sprinkler system

-On the basis of arrangement for spraying irrigation water

1. Rotating head (or) revolving sprinkler system
2. Perforated pipe system

- Based on the portability

1. Portable system:

It has portable mainlines and laterals and a portable pumping unit

2.Semi portable system:

A semi portable system is similar to a fully portable system except that the location of the water source and pumping plant are fixed.

3.Semi permanent system:

A semi permanent system has portable lateral lines, permanent main lines and sub mains and a stationery water source and pumping plant.

The mainlines and sub-mains are usually buried, with risers for nozzles located at suitable intervals.

4. Solid set system: A solid set system has enough laterals to eliminate their movement. The laterals are placed in the field early in the crop season and remain for the season.

5. Permanent system: It consists of permanently laid mains, sub-mains and laterals and a stationary water source and pumping plant. Mains, sub-mains and laterals are usually buried below plough depth. Sprinklers are permanently located on each riser.

Advantages

1. Water saving to an extent of 35-40% compared to surface irrigation methods.
2. Saving in fertilizers - even distribution and avoids wastage.
3. Suitable for undulating topography (sloppy lands)
4. Reduces erosion
5. Suitable for coarse textured soils (sandy soils)
6. Frost control - protect crops against frost and high temperature
7. Drainage problems eliminated
8. Saving in land
9. Fertilisers and other chemicals can be applied through irrigation water

Disadvantages

1. High initial cost
2. Efficiency is affected by wind
3. Higher evaporation losses in spraying water
4. Not suitable for tall crops like sugarcane
5. Not suitable for heavy clay soils
6. Poor quality water can not be used (Sensitivity of crop to saline water and clogging of nozzles)

Steps to be taken for reducing the salt deposits on leaves and fruits during sprinkler irrigation

- Irrigate at night
- Increase the speed of the sprinkler rotation
- Decrease the frequency of irrigation