UNIT 8 SPRINKLER AND DRIP IRRIGATION SYSTEMS

Structure

8.1 INTRODUCTION

It is well appreciated that a gross cropped area could yield more, as well as be, virtually increased in extent by increasing the intensity of cultivation with the limited available water. This would necessitate continuous development, and application of technology to conserve water resources and increase the efficiency of water utilization. Adoption of water saving methods, in the practice of irrigation, like, sprinkler and drip irrigation, provide a means of increasing the efficiency of irrigation.

Sprinkler and drip irrigation systems fall under a category known as *pressurised irrigation*. In pressurised irrigation systems, application of water is through pressure devices and flow is essentially through pipes. Sprinkler and drip irrigation systems are very popular in countries, like, U.S.A., Australia, Israel, Europe etc., but these have not become popular with the farmers in general in India. However, many cultivators of tea, coffee and vegetables in the country are using sprinkler irrigation system, while coconut and orchard farmers have been using drip irrigation system for the past ten to fifteen years. In order to increase crop production, to cope with the population growth, more area of land, as mentioned, needs to be brought under irrigation as quickly and easily as possible; and one of the ways to do it is to introduce sprinkler and drip irrigation systems in coming years replacing surface methods in respect of certain crops and certain locations.

The sprinkler and drip irrigation methods have a role to play in India in regions of water scarcity and where water is insufficient to irrigate the command area by surface irrigation method. An overview of these two irrigation systems with their adaptability for various conditions of topography, soils, crops as well as their limitations is presented in this unit.

Both these irrigation methods have quite a few basic features in common. Besides, both these methods are economical in their use of water as surface runoff and deep percolation losses are eliminated. Soil erosion as well as drainage problem are also avoided and good control over the use of water is possible with both the methods. Distribution of fertilizers is possible through both the systems although there are some limitations. Also, both the systems are expensive in their initial cost. In order to minimize the investment and operating costs, both the systems require careful planning, design and operation, and call for adequate knowledge of engineering and agricultural principles. Although there are several features in common between these two systems, each system is best suited to certain particular conditions.

Objectives

After studying this unit, you should be able to:

- appreciate the importance of both sprinkler and drip irrigation system,
- know the various components of these two systems, and
- design the basic elements of these systems.

8.2 SPRINKLER IRRIGATION

Applying sprinkler irrigation is similar to exposing crops to natural rainfall. Water is pumped through a pipe system and then sprayed on to the crops through rotating sprinkler heads. The spray is developed by converting pressure within the nozzle of the sprinkler into velocity to produce a high energy jet, falling on the crops. As the jet passes over the field, it breakes up and water droplets drop down as a spray. These droplets meet with air resistance and under gravity evenly fall to the ground, with some evaporation taking place in the air. In most conventional sprinkler systems, designed application rates are less than the infiltration rates of the soil. Thus, all water reaching the ground surface infiltrates into the top soil, and there is no movement of water over the soil surface. Failure to limit the application rates or designing the system to allow for surface water movement, can result in non-uniform application of water or serious erosion problems. With appropriate selection of nozzle size, operating pressure and sprinkler spacings, water can be applied efficiently and fairly uniformly to fill in the root zone.

Suitability of Sprinkler Irrigation

Sprinkler irrigation can be adopted for almost all crops except rice and jute, and also on most types of soils under varying topographic conditions. However, it is best suited under the following conditions :

i) Sandy soils or soils with high infiltration rate.

ii) Shallow soils, where levelling and shaping operations are likely to expose the subsoil.

iii) Undulating topography or steep slopes where levelling or shaping operations is not economical.

iv) The available irrigation stream being too small for surface flow.

v) Need to bring the land into production quickly and economically. We know that in surface irrigation, the required land development, construction of channels, levees, basins, furrows etc., take time, and besides it involves expensive construction and maintenance costs as well as loss of about 6 to 7 per cent space which can otherwise be put into use.

The main uses and advantages of sprinkler system are :

i) Possibility of light and frequent irrigation with obvious advantages, good germination under soil crusting, control of soil and crop canopy temperature, and control of frost and humidity.

ii) Application of fertilizers, pesticides and weedicides and their better utilization.

iii) Elimination of loss of water by seepage.

There are, however, the following limitations that are attributed to sprinkler irrigation systems :

i) Under windy conditions (16 km/hour) and high temperatures, the water distribution and water application efficiencies are low.

ii) Saline water may cause leaf burns in many crops.

iii) System is costly to install, operate and maintain.

iv) Continuous supply of power is generally required for operating the system.

v) Corners remain under-irrigated and therefore uniformity of application is to some extent affected.

8.2.1 Types of Sprinklers

On the basis of the arrangements adopted for spraying irrigation water, sprinkler systems are classified into three types, such as :

i) Fixed nozzles attached to a pipe,

ii) Rotational head /revolving sprinkler, and

iii) Perforated pipe system.

Fixed Nozzle

Earlier all the sprinkler systems were fixed-nozzle type. Parallel pipes are installed about 15m apart which are supported on rows of posts. Water is discharged at right angles to these pipes. The entire 15m space between pipe lines may be irrigated by turning the pipes through 135° about respective longitudinal axes.

Revolving Sprinkler

There are three categories of this type of arrangement, such as:

a) Conventional system / small rotary sprinkler,

b) Boom type and self propelled, and

c) Mobile raingun / large rotary sprinkler.

Conventional system

Small size nozzles are placed on riser pipes that are fixed at uniform intervals along the length of a lateral pipe. The laterals are usually laid on the ground surface. In this method, the most common device to rotate the sprinkler head is a small hammer actuated by the thrust of the water striking against a vane connected to it. This system is commonly used since it operates at low to medium pressure intensities, and it can irrigate an area with dimensions of 9 to 24 m wide and upto 300m long in one setting with an application rate of about 5.35mm per hour.

Boom Type

This system employs one boom sprinkler in each lateral. A boom is basically a nozzle, slowly rotating from a pipe sprinkler which is moved by towing the towers to the next position along the laterals with a tractor. A large size sprinkler irrigates a width of 75-100 m depending on the nozzle size and the pressure, and is particularly useful for tall crops.

Mobile Raingun

The system operates at a high pressure to irrigate comparatively large areas, because it is able to throw a large quantity of water over wide areas. It can irrigate areas upto 4 ha at one setting with an application rate of 5 to 35 mm per hour. There are two types of this system, namely, hose pull system and hose reel system.

Perforated System

This set-up consists of drilled holes along the length of each nozzle through which water is sprayed under pressure. This system is usually designed for relatively low operating pressures. The application rate is 1.25-5cm per hour for various pressures and spacings.

Further, based on portability, the sprinkler systems are classified into following three types :

i) Portable system,

ii) Solid set / Permanent system, and

iii) Semi-permanent system.

Portable System

The simplest portable system is designed to be moved by hand power. It consists of a pump, main line, a lateral and a rotary sprinkler spaced at 9 to 24 m apart. A lateral is usually between 50 mm to 100 mm in diameter. It remains in position until irrigation is complete. The pump is then stopped and the lateral disconnected from the main line and water is allowed to drain off. It is then dismantled and moved by hand to next point and reassembled. Usually it is moved about 1 to 4 times each day. It is gradually moved around the field until the entire field is irrigated (Figure 8.1). In some cases the entire system including pump and the main line is moved from field to field. Portable system is common in India since the capital investment is low and it is simple to use.

Solid Set /Permanent System

When sufficient laterals and sprinklers are provided to cover the entire area to be irrigated, there is no need to move the equipment from place to place. This system is termed as solid set or permanent system. This is used for high value crops such as in orchards, vine yards, etc.

Semi-Permanent System

Many new sprinkler systems have been developed in recent years with the advantage of being both portable and solid set, thus reducing capital cost and labour requirements. These are known as semi-permanent systems.

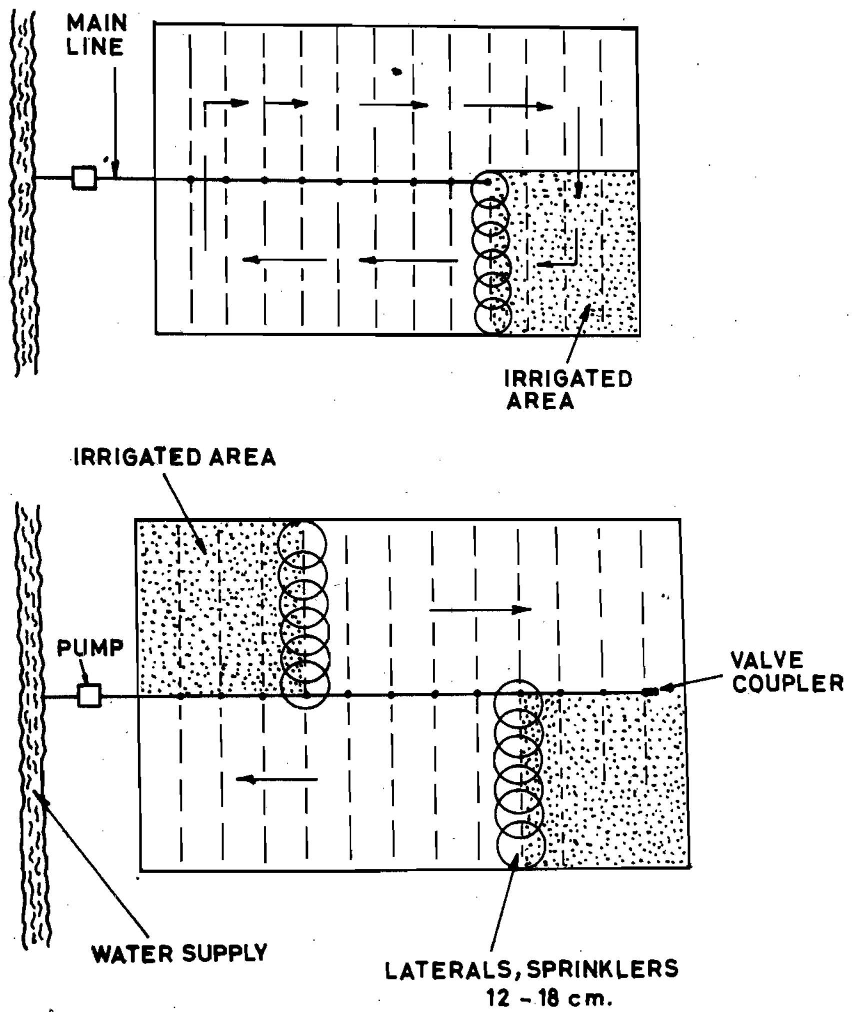


Figure 8.1: Portable System Using One / Two Laterals

Operating Pressure and Adaptability

Table 8.1 gives the classification of sprinklers and their adaptability on the basis of operating pressures.

Table 8.1: Classification of Sprinklers and their Adaptability

Type of Sprinkler	Low Pressure 5-15 psi (0.35-1 kg /sq cm)	Moderate Pressure 15-30 psi (1-2 kg/sq cm)	Intermediate Pressure 30-60 psi (2.4 kg/sq cm)	High Pressure 50-100 psi (3.5 kg/sq cm)	Hydraulic or Giant 80-120 psi (5.6-8.4 sq cm)	Undertree Low Angle 10.5 psi (0.7-3.5 kg/sq cm)	Perforated 4-20 psi (0.28-1.4 kg/sq cm)
1	2	3	4	5	6	7	8
General characteristics	Special thrust springs of reaction type arms	Usually single nozzle oscillating or long-arm dual nozzle design	Either single or dual nozzle design	Either single or dual nozzle design	One large nozzle with smaller supplemental nozzles to fill in pattern gaps. Small nozzle rotates the sprinkler	Designed to stream trajectories below fruit and foilage by lowering the nozzle angle	Portable irrigation pipe with lines of small perforations in upper third of pipe perimeter
Range of wetted diameter	6 to 15 cm	15 to 24 cm	23 to 37 cm	33 to 70 cm	60 to 120 cm	12 to 27 m	Rectangular strips 3-15 m wide
Recommended mini. Application rate	1.0 cm /hr	0.5 cm/hr	0.62 cm/hr	1.25 cm/hr	1.6 cm/hr	0.83 cm/hr	1.25 cm/hr
Jet characteristics (assuming proper pressure and nozzle size relations)	Water drops are large due to low pressure	Water drops are surely well broken	Water drops are well broken over entire wetted diameter	Water drops are well broken over entire wetted diameter	Water drops extremely well broken	Water drops are surely well broken	Water drops are large due to low pressure
Moisture distribution pattern (assuming proper spacing and pressure nozzle size)	Fair	Fair to good at upper limits of pressure range	Very good	Good except where wind velocities exceed 4 miles /hr.	Acceptable in calm air severely distorted by wind	Fairly good diamond pattern recommended where laterals are spaced more than one tree interspace	Good pattern is rectangular

8.2.2 Sprinkler System Components

Pump

The basic unit of a sprinkler system essentially consists of a pump (except when pressure can be obtained by gravity), the main pipe network and sprinkler lines (laterals with risers and sprinkler heads). The accessories consist of debris screens, desilting basin, booster pumps, take-off and flow control valves and fertilizer application unit.

Both volute centrifugal pumps and deep well turbine pumps are used to operate sprinkler systems. Centrifugal pumps are more common with shallow water sources. Electric motors or internal combustion engines are used to drive these pumps.

Main and Lateral Lines

Main lines may be permanent or portable. Main lines are made of steel, asbestos cement, PVC or light aluminium. Laterals are usually portable except in some cases like for orchards or other specific sites, where they are permanently buried. The lateral pipes are available in lengths of 3, 6 or 12 m. Quick coupled aluminium pipes are best suited for lateral sprinkler lines. The risers are spaced along the laterals, and on these risers are located the sprinkler heads.

Sprinkler Head

A sprinkler head is functionally the most important component in a sprinkler irrigation system. Its operating characteristics under optimum water pressure and climatic conditions, mainly the wind velocity, determine the suitability and the efficiency of the system. The two principal methods used to develop the spray required for sprinkling are the use of perforated pipes and rotating sprinklers. The perforated spray lines comprise holes in the lateral lines in a specially designed pattern to distribute the water evenly. Water is applied at a relatively higher rate, and therefore the perforated pipe system is suited to soils having moderately high infiltration rates. It is also suited for vegetable crops and other plants when their height does not exceed 40-60 cm. The system is usually designed for low operating pressure ranging from 0.5 to 2.5 kg /cm^2. The spray is directed on to both the sides of the pipe, and can cover a strip of land 6 to 15 m wide.

The rotating or revolving head sprinklers are either fast rotating (also called *reaction sprinklers*) or slow rotating, single or two nozzle sprinklers or intermittently or continuously rotating sprinklers.

Most agricultural sprinklers are slow rotation type, ranging from small single nozzle to giant multiple nozzle sprinklers that operate at high pressures. The combination of pressure and slow rotation results in the jet of water being thrown to a considerable distance. The most common device to rotate the sprinkler head is a small hammer activated by the thrust of water striking against a vane connected to it.

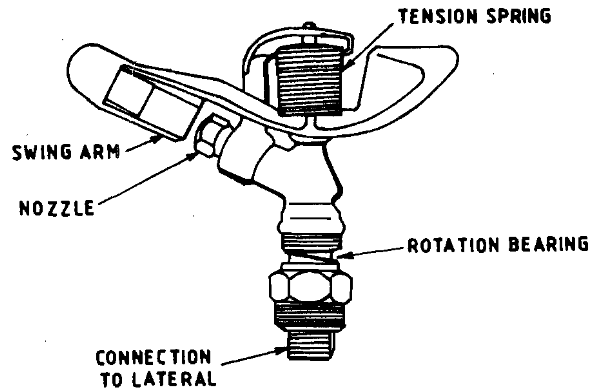


Figure 8.2: Components of Sprinkler

Single nozzle sprinklers are used for low water application rates. The commonly used two nozzle sprinklers apply water at a relatively higher rate and provide better uniformity of application. Of the two nozzles one applies water at a considerable distance and the other covers the area near the sprinkler centre. Figure 8.2 shows the components of a rotating sprinkler head.

The fertilizer applicator unit installed with the sprinkler system consists of a sealed tank with necessary tubings and connections. The fertilizer is introduced into the system from the suction side of the pump through a pipe and regulated by a valve. Another pipe connects the discharge side of the pump to the container having a charge of fertilizer, for required water supply in the tank. Figure 8.3 shows the components of a sprinkler system.

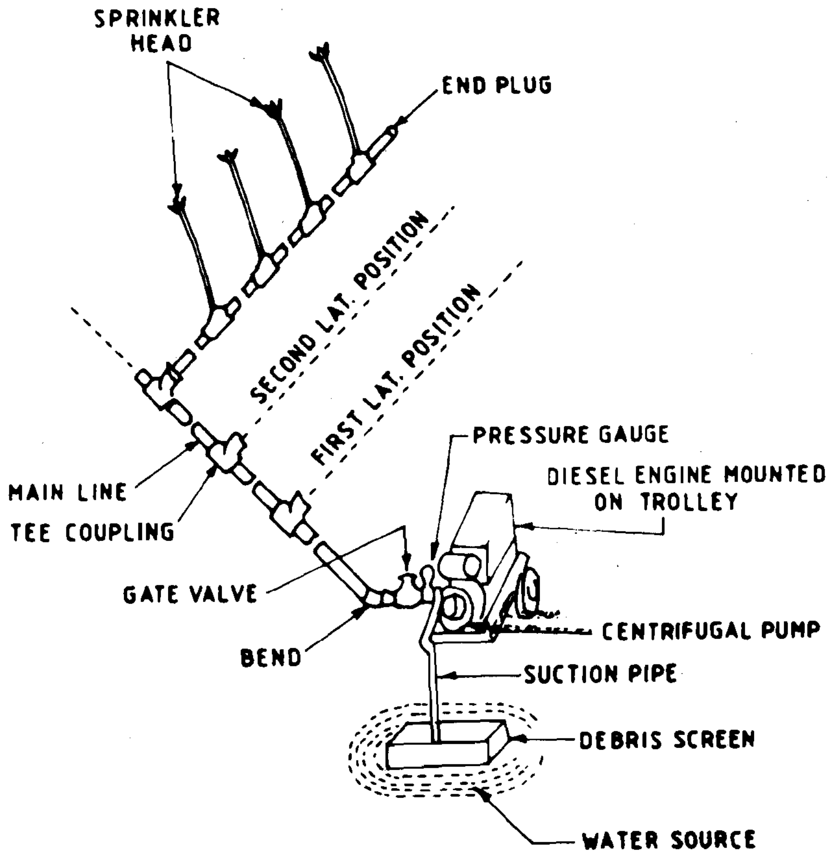


Figure 8.3: Components of Sprinkler Irrigation System

8.2.3 Design of Sprinkler System

To design a sprinkler irrigation system, some basic data are needed, such as, discussed below :

i) **Water supply**

It concerns the location of water delivery point, quality (chemical composition, especially amount and type of salts present), and the delivery schedule. Water should obviously be clean and free from impurities. It is essential that the available flow of water should be sufficient to meet the peak crop water requirement.

ii) **Soil characteristics**

Soil type, depth, texture, water intake rate and available water holding capacity upto root zones (Table 8.2), are the important soil characteristics influencing the design. The application rate should be such that it would not generate runoff. Table 8.3 gives the guidelines for the selection of application rate under various soil and slope conditions.

iii) **Crop factors**

These include peak consumptive use per day, depth of root zone, and leaching requirement.

Table 8.2: Soil Moisture Holding Capacities of Different Soils

Sl. No.	Soil Texture	Moisture Holding Capacity (mm of water/cm of depth)
1	Very coarse texture - coarse sand	0.33 to 0.58
2	Coarse texture, sands, fine sands and loamy sands	0.67 to 1.05
3	Moderately coarse texture - sandy loams	1.05 to 1.46
4	Medium texture - very fine sandy loams and silty loams	1.25 to 1.92
5	Moderately fine texture – clay loams and sandy clay loams	1.46 to 2.10
6	Fine texture - sandy clay, silty clays and clays	1.35 to 2.10
7	Peat and muck	1.66 to 2.50

Table 8.3: Suggested Maximum Application Rates for Sprinklers for Average Soil and Slope

Sl. No.	Soil Texture and Profile	Suggested Maximum Application Rate (Cm/hr)			
		.0 - 5% Slope	5-8% Slope	8 - 12% Slope	12 - 16% Slope
1	Coarse sandy soil upto 2m	5.10	3.75	2.54	1.27
2	Coarse sandy soil over more compact soils	3.75	2.54	1.90	1.02
3	Light sandy loam upto 2m	2.54	2.03	1.50	1.02
4	Light sandy loams over more compact soils	1.90	1.27	1.02	0.76
5	Silty loams upto 2m	1.27	1.02	0.76	0.51
6	Silty loams over more compact soils	0.76	0.63	0.51	0.25
7	Heavy textured clays and clay loams	0.38	0.25	0.25	0.15

Source: *Sprinkler Irrigation Guidebook*, USAID, Washington, DC 1968

iv) **Topographic features**

Complete information on topography of the field is necessary to determine the extent of the available pressure at a given sprinkler head. A contour map of the area drawn to a scale should be made available to the designer to work out levels at different locations

v) **Climatic factors**

The climatic factors have a substantial effect on effective rain fall, and the design of the system. Wind velocity badly affects the performance of the sprinkler as it contributes to deflecting the spray from the intended direction. The following percentages of effective wetted diameter should be considered as maximum spacing for laterals, for different wind conditions :

Wind Velocity	*Lateral Spacing*
<8 km /hr	65% of the effective wetted diameter
8 km /hr	60% of the effective wetted diameter
8-16 km /hr	50% of the effective wetted diameter
>16 km /hr	30% of the effective wetted diameter.

vi) **Available sprinkler equipment**

Knowledge of the available sprinkler equipment in the market is very useful for designing a system. Manufacturers provide performance tables relating to nozzle size, operating pressure, diameter of spray, discharge rate of the nozzles and application rates for different spacings. It becomes, therefore, easy to select suitable equipment to meet the desired field conditions and operating requirements.

Basic Design Parameters

A sprinkler irrigation system is specifically designed in order to achieve high efficiency in its performance according to the given site conditions; and, it is, however, very seldom that one set of conditions will be duplicated in the field. The design of a sprinkler system includes the most feasible layout of its mainlines, the layout and spacing of laterals, the required size of laterals and mainlines, and the required capacity of the pump. A definite plan of operation ensuring irrigation of the entire area within the permissible interval between irrigations during the period of maximum evapotranspiration must be chalked out. Under normal conditions, the most satisfactory operating schedule involves one to two or a maximum of three moves of sprinkler laterals per day. However, for greater application and for soils with low intake rates, one lateral move per day is more desirable. Usually, several laterals supplied by a central mainline will prove most economical.

For the purpose of explaining the basic design considerations an example of a single rectangular area (4 ha) is chosen with known data from a specified location, which is discussed as follows:

Step 1: Inventory of Resources

Location	:	Semi-arid region
Soil	:	Moderately coarse sandy loam upto 2m depth with natural drainage
Water source	:	Well which is adequate for irrigation
Power source	:	Electricity (3 - Phase) is available for 12 hours
Crop	:	Groundnut and Blackgram
Climate	:	No effective rainfall during the peak consumptive use.

Step 2: Water to Apply for each Irrigation

From Table 8.2 the total available water holding capacity of soil on this farm ranges from 1.05 to 1.46 mm /cm depth. Using an average value of 1.25 mm /cm, and a moisture extraction depth of 60 cm, the total available moisture is about 7.5 cm. On the basis of the assumption that not more than 50% of this moisture would be used up, the maximum amount that is to be applied at each irrigation is about 3.75 cm or say, 4 cm.

Step 3: Cycle of Rotation or Frequency

Time interval between successive irrigations during the peak consumptive use of the crop is a function of frequency of irrigation. Using the value of water requirment as 0.53 cm /day (for groundnut crop), the cycle of rotation works out to be seven days (=3.75/0.53); for blackgram it works out to be 8 days $\left(= \frac{3.75}{0.44}\right)$. These water requirment values were obtained in the field in respect of the example under discussion.

Step 4: Capacity of the System

The system requirement or pump capacity is calculated by the following equation:

$$Q = \frac{A \times D \times 27.8}{F \times H \times E} \quad \text{... (8.1)}$$

where, Q = Flow through pump, in l /s

A = Area in hectares

D = Depth of application in cm

F = Irrigation interval in days

H = Duration of operation, in hours/day

E = Field application efficiency (fraction)

On the basis of 12-hours-per-day operation, and a field application efficiency of 0.80, the required capacity of the pump is given by:

$Q = ((4 \times 3.75 \times 27.8)/(7 \times 12 \times 0.8)) = 6.2.1$ /s (Groundnut)

$Q = ((4 \times 3.75 \times 27.8)/(8 \times 12 \times 0.8)) = 5.4$ l /s (Blackgram)

Therefore, take the design discharge = 6.2 l /s

Step 5 : Optimum Water Application Rate

This is determined by the type of soil and crop, and the slope of land; and also it is to be considered whether the application rate is to be without puddling or surface runoff. In this problem, the slope is fairly uniform, averaging about 2 per cent, and as there may be periods when crop protection is negligible the maximum application rate is 1.5 cm/hour (as per the actual field data collected). Sprinkler selection and spacing must be so as the rate of application of water does not exceed this maximum rate.

Step 6: Selection of Sprinkler

First work out an optimum arrangement of main and laterals in respect of the topography and operation and then determine the sprinkler spacing and discharge. In this example, we know that the field must be irrigated in a minimum of seven days. If the farm operator prefers two moves, then not more than 14 moves are possible in the case of one lateral or seven moves with two laterals.

We have certain basic limitations on maximum space intervals between moves which for the typical intermediate pressure sprinkler is 18m. In our example, the location of the main would ideally be through the centre of the field, and with 18m intervals for lateral moves there will be a total of 11 lateral sets by locating the first and the last positions 9 m from the edge of the field. If 15m move intervals were selected, there would be 13 sets.

With the management plan allowing to move the lateral twice a day, the field could be covered with two laterals equal to half the width of the field in seven days using the 15m interval. Thus, either arrangement is satisfactory in respect of time element. Let us select the option of one lateral operating at a time.

Step 7: Number of Sprinklers Required

After selecting sprinkler spacings decide upon water application rates. Here again it is necessary to establish a maximum spacing of the sprinklers on the lateral which for intermediate sprinklers is generally accepted at 12 m. Closer spacings are acceptable under more windy conditions; thus, we may consider 9 m and 12 m sprinkler spacing. In our example, this becomes 11 or 8 sprinklers, respectively, by locating the first and the last sprinkler 5m from the mainline and the edge of the field.

We therefore have four possible move-spacing alternatives available for selection— $18 \times 12m$, $18 \times 9m$, $15 \times 12m$, and $15 \times 9m$. Application rates in each case are determined by the following formula:

Water application rate = $((360 \times q) / (S_1 \times S_2))$

i.e., Water application rate = ((lps of sprinkler × 360) / (spacing × move in metres))

In this example, herein, we can, thus, tabulate the results as follows :

Spacing × move	No of sprinklers	Sprinkler size (lps)	Appln rate (cm /hr)
18 × 12m	8	6.2/8 = (0.8)	1.33
18 × 9m	11	6.2/11 = (0.58)	1.29
15 × 12m	8	0.80	1.60
15 × 9m	11	0.58	1.54

All the various alternatives are perhaps sufficiently close to each other; however, a good selection seems to be 15 × 9m arrangement as it has the advantage of a low application rate plus the fact that in windy conditions, the closer sprinkler spacing on the lateral will permit more overlap and better distribution efficiency as compared to 18 × 12m arrangement.

The next step requires referring to the sprinkler manufacturers catalogue to select the nozzle, pressure and the wetted diameters to meet the requirements. With the 0.58 lps sprinkler discharge the nozzle combination is 4.76mm × 3.2mm for a typical double nozzle sprinkler operating under a pressure of 2.8 kg /sq cm with wetted diameter of about 30m. Typical information about a rotary sprinkler is shown in Table 8.4.

General Guidelines for Spacing of Sprinklers

Following guidelines, to determine the spacing of sprinklers, are pertinent:

i) For low to moderate-pressure sprinklers (0.35-4.00 kg /sq cm) following spacings are generally maintaned— a) for upto 6 km/hr wind conditions do not exceed 50% of wetted diameter of the sprinkler as the spacing of the sprinkler in the lateral line, and 65% of the wetted diameter for the distance of the lateral move to its next position, and b) for winds of 6 to 15 km /hr reduce the magnitude of spacings given above and do not exceed 40% and 50% of wetted diameter, respectively.

ii) For high pressures and giant sprinklers (3.5 to 7 kg /sq cm), the spacing should lie within 50-60% for both the windy conditions.

Pressure ranges are defined as under:

Low pressure	0.35-1.00 kg /sq cm (5-15 psi)
Moderate pressure -	1.00-2.00 kg /sq cm (15-30 psi)
Intermediate pressure -	2.00 - 4.00 kg /sq cm (30-60 psi)
High pressure -	3.50 - 7.00 kg /sq cm (50-100 psi)

Step 8: Layout of the System

Having completed the basic design, as explained in the above mentioned steps, its essential features are listed below :

Water to apply	=	3.75 cm
Peak water requirement	=	0.53 cm/day
Max. irrigation interval	=	7 days
Pump capacity	=	6.2 lps
(@ 80% field application efficiency)		
Sprinkler spacing	=	15m × 9m
Type of sprinkling	=	Intermediate pressure

Table 8.4: Rotary Sprinkler Model: Twin Nozzles

Nozzle Pressure kg/cm^2	Nozzle 3.96 mm × 2.38 mm		Nozzles 4.36 mm × 2.38 mm		Nozzle 4.76 mm × 2.38 mm		Nozzle 4.76 mm × 3.2 mm		Nozzle 5.16 mm × 3.2 mm		Nozzle 6.5 mm × 3.2 mm		Nozzle 7.15 mm × 3.2 mm	
	Dia. (m)	Disch. (l /s)	Dia. (m)	Disch. (l /s)	Dia. (m)	Disch. (l /s)	Dia. (m)	Disch (l /s)	Dia. (m)	Disch (l /s)	Dia. (m)	Disch (l /s)	Dia. (m)	Disch (l /s)
1.7	25.9	0.3024	26.5	0.3486	-	-	-	-	-	-	-	-	-	-
2.1	27.4	0.3320	27.1	0.3835	29.0	0.4350	29.0	0.5131	-	-	-	-	-	-
2.5	28.1	0.3585	29.9	0.4366	29.9	0.4737	29.9	0.5548	30.5	0.6253	-	-	-	-
2.8	28.4	0.3858	29.3	0.4434	30.5	0.5017	30.5	0.5793	31.4	0.6738	32.3	0.7489	34.2	1.0991
3.2	-	-	-	-	31.1	0.5796	31.1	0.6374	32.0	0.7125	32.9	0.0884	35.4	1.1643
3.5	-	-	-	-	32.6	0.5824	32.6	0.6487	32.6	0.7489	33.5	0.8413	36.4	1.2219
3.8	-	-	-	-	-	-	-	-	-	-	34.2	0.8717	37.2	1.2686

Mainline	=	200m with lateral outlet at each 15m
Laterals	=	95m with 11 sprinklers each spaced at 9m.
Sprinkler capacity	=	0.58 l/s
Application rate	=	1.5 cm/hr
Hours per lateral set	=	6 hrs
Total gross application	=	4.5 cm ($\simeq$ 3.75 /0.80)

The above design meets all the basic requirements.

Lateral Design

A minimum diameter pipe should be selected as a lateral which is consistent with good sprinkling performance. A 20% pressure variation results in about 10% difference in nozzle discharge, and this maximum pressure variation between the first and the last sprinkler on a lateral has been generally accepted as a design criterion.

Friction Loss and Multiple Outlet Connection–Step by Step Procedure

Friction loss in pipes is a major source of depletion of hydraulic energy. An outline of the procedure to account for it in the overall design is given below :

i) Select a pipe size,

ii) Determine friction loss assuming that the flow takes place through the entire length of the pipe without sprinklers in place,

iii) Use an appropriate correction factor depending on the number of outlets to determine actual losses,

iv) Add the elevation if the lateral goes uphill or subtract the drop if the lateral goes downhill, and

v) Compare with the allowable 20 per cent loss; and if it is approximately the same the selection is appropriate, otherwise repeat the procedure right from step i).

For our problem, the selected sprinkler has the average design pressure of 2.8 kg /sq cm which will exist at mid-point on the lateral. A 20 per cent variation works out to be 0.56 kg /sq cm which corresponds to an elevation of 5.6m.

The other conditions are 11 sprinklers, each discharging 0.58 l /s with 95m lateral. The lateral location in this example permits part downhill and part level placement.

Trial size selected = 7.5cm (diameter)

Friction loss through the pipe without outlets is computed using the Scobey's formula which is given by

$$H_f = 2.59\ K_s \frac{V^{1.9} L}{1000 \times D^{1.1}} \qquad \text{... (8.2)}$$

Hf	=	Friction loss (meters)
K_s	=	Coefficient of retardation (K_s = 0.36 for Cast iron & K_s = 0.32 for PVC)
L	=	Pipe length, meters,
V	=	Velocity of flow (m /sec).
D	=	Diameter of pipe in (metres)

The emiprical equation for computing the correction factor, F, for multiple outlets is

$$F = \frac{1}{(m+1)} + \frac{1}{2N} + \frac{m-1}{6N^2} \qquad \text{... (8.3)}$$

in which, $m = 1.9$ (Velocity exponent in Scobey's formula)

N = Number of outlets in the line

Flow in laterals = No. of sprinklers × discharge per sprinkler

$= 11 \times 0.58 = 6.38\ l/s$

$$V = \frac{Q}{A} = \frac{\frac{6.38}{1000}}{\frac{\pi\, 0.075^2}{4}} = 1.444 \text{ m /sec}$$

Selecting a later size of 7.5 cm (diameter), head loss in the lateral is given by :

$$H_f = 2.59 K_s \frac{V^{1.9} L}{1000 \times D^{1.1}}$$

Selecting laterals of PVC pipe;

$$H_f = 2.59 \times 0.32 \times \frac{1.444^{1.9} \times 95}{1000 \times 0.075^{1.1}}$$

$= 2.73$ m

Friction loss correction factor,

$$F = \frac{1}{2.9} + \frac{1}{2 \times 11} + \frac{0.9}{6 \times 11^2}$$

$= 0.392$

∴ Actual head loss due to friction $= 0.392 \times 2.73$

$= 1.07$ m

Adopting a φ (diameter) of 5 cm in the lateral, we have :

$$V = \frac{\frac{6.38}{1000}}{\frac{\pi \times 0.05^2}{4}} = 3.249 \text{ m/sec}$$

$$H_f = 2.59 \times 0.32 \times \frac{3.249^{1.9} \times 95}{1000 \times 0.05^{1.1}} = 19.94 m$$

F = 0.392 m (as shown as above)

Actual $H_f = 19.94 \times 0.392 = 7.82\ m.$

This exceeds the allowable limit namely 5.6 m. Hence, 7.5 cm diameter PVC pipe can be adopted.

It has been well established that the friction loss along a lateral of uniform size decreases rapidly with three-fourth of the total loss occuring in the first half of the length. Thus the pressure at the first sprinkler will be equal to the average design pressure plus the three-fourth of the lateral head loss. On the other hand, the pressure at the end sprinkler will be equal to the average design pressure minus one-fourth of the lateral head loss. In order that all the sprinklers work properly these two extreme prressures should be within the operating pressure range of the selected sprinkler.

Pressure at the first sprinkler $= 2.8 \times 10 + (\frac{3}{4} \times 1.07) = 28.80\ m = 2.88\ {}^{kg}/_{cm^2}$

Pressure at the last sprinkler $= 2.8 \times 10 - (\frac{1}{4} \times 1.07) = 27.73\ m = 2.77\ {}^{kg}/_{cm^2}$

The variation is within the permissible limit as specified for the selected sprinkler, namely, 2.1 kg /cm^2 and 3.5 kg /cm^2 (Table 8.4).

Main Line Design

In contrast to lateral design there are no specific standards as to the amount of allowable losses for mainline pipe. Designers usually consider as reasonable a mainline loss of about 3m for small systems and upto about 12 m for large systems.

The main line is about 200 m long with a flow of 6.38 *l/s*. Its friction loss can be calculated as follows:

Select 10 cm as the diameter size. We have :

$$V = \frac{6.38 \times 4}{\pi \times 0.1^2 \times 1000} = 0.812\,{}^{m}\!/_{sec}$$

$$H_f = 2.59 \times 0.32 \frac{0.812^{1.9}}{0.1^{1.1}} \times \frac{200}{1000} = 1.405 < 3m$$

If 7.5 cm diameter is selected, we have

$$V = \frac{6.38 \times 4}{\pi \times 0.075^2 \times 1000} = 1.444\,{}^{m}\!/_{sec}$$

$$H_f = 2.59 \times 0.32 \frac{1.444^{1.9}}{0.075^{1.1}} \times \frac{200}{1000} = 5.8 \text{ m}$$

Adopt 10 cm as the diameter of the main line.

A schemtic diagram showing the designed layout is given in Figure 8.3(a).

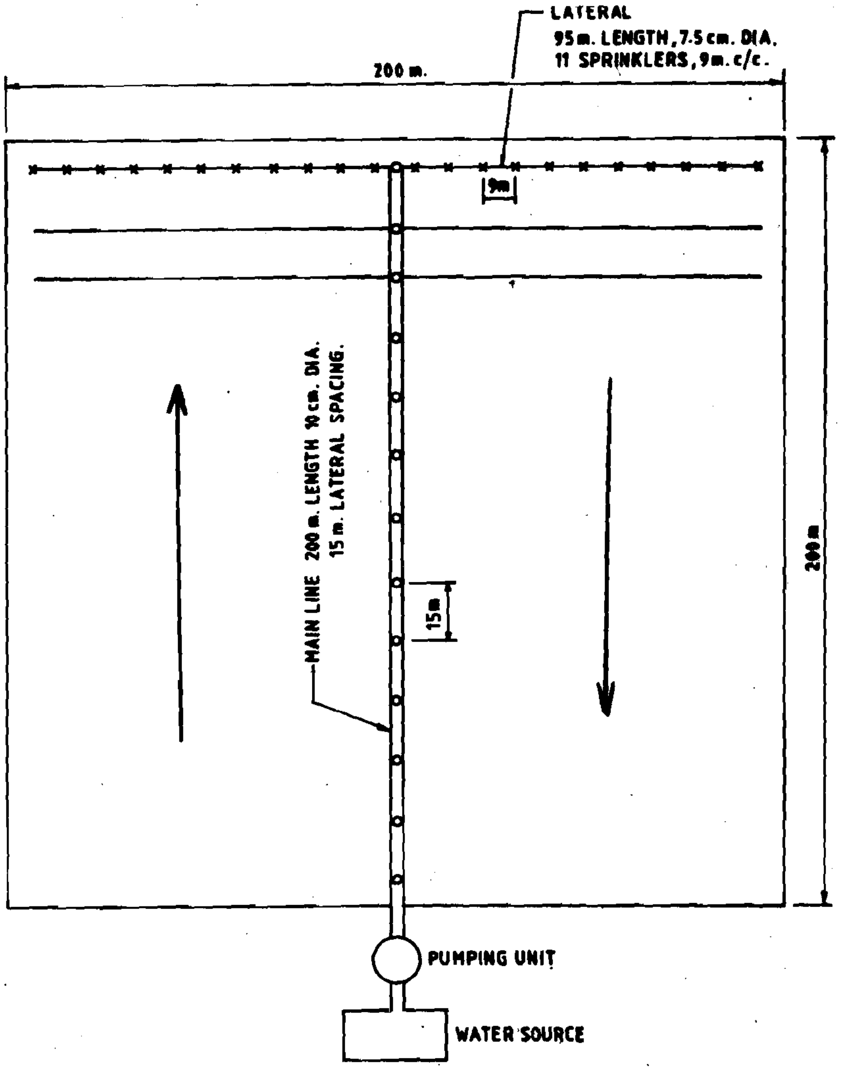


Figure 8.3(a): Designed Layout of Sprinkler Irrigation System

Pump Design

The pump should be designed to meet the requirements of total dynamic head and total static head for the sprinkler system. For the following cmsting, namely,

Pressure head at last sprinkler	=	27.73 m
Friction in lateral	=	1.070 m
Friction in main line	=	1.405 m
Riser Height	=	0.600 m
Minor losses (3 m assumed)	=	3.000 m
Total sprinkler head	=	33.805 m

We can compute the total dynamic head as follows :

Total delivery head at the pump	=	$10.2 + (10.2 \times 0.15)$
	=	11.73 m
Total dynamic head	=	$33.805 + 11.73 = 45.54 \simeq 46$ m

Assuming 60% efficiency (η), the required pump capacity is computed as under :

$$HP = \frac{QH}{75\eta} = \frac{6.38 \times 46}{75 \times 0.6} = 6.5HP \qquad \ldots (8.4)$$

Adopt a pump with a capacity of 7.5 HP.

SAQ 1

Sprinklers that discharge 25 l /min and have a wetted diameter of 30 m are spaced 15 m apart along a lateral. The spacing between the laterals is 18 m. Determine the application rate of the sprinkler.

SAQ 2

A 300 m long sprinkler lateral discharge is 500 l /min. The spacing between the laterals is 15 m. Determine the average application rate of the sprinkler lateral.

SAQ 3

Ten 300 m long laterals with sprinklers at a 15 m square spacing pattern are operated simultaneously to irrigate a 25 ha. field. The system is designed to deliver a daily irrigation requirement of 7 mm /day and a desired depth of irrigation of 15 mm Determine the maximum time between the successive irrigations?

SAQ 4

Use the information from SAQ 3 to determine the sprinkler capacity needed for a set length of time of 8 hr.

8.3 DRIP IRRIGATION

Drip or *trickle* irrigation is one of the most recent developments in the practice of irrigation. It was developed in Israel by Simca Blass, a Water Engineer, in the year 1959. Drip irrigation has many potential advantages when compared with other methods of irrigation. The most important of these are: increased crop yields, high irrigation efficiency, low energy requirements and low labour requirements. A typical drip irrigation system is illustrated in Figure 8.4. Drip Irrigation is also called *micro-irrigation, drop irrigation, and sip irrigation.*

Under this system, water and fertilizer are placed directly near the root zone of the plants. This is achieved with the help of specially designed emitters and drippers. The emitters develop a tension in the system. Most emitters are placed on the ground, but they can also be buried. The wetted soil area for widely spaced emitters will normally be elliptical in shape as illustrated in Figure 8.5. Since the area wetted by each emitter is a function of the soil and its hydraulic properties, one or more emission points per plant may be necessary for a satisfactory action.

Adaptability of Drip System

A large variety of orchard crops, coconut, vegetable crops, row and field crops and flowers–in fact almost all crops except rice and jute are being successfully grown with drip system of irrigation. Drip system may not, however, be economical for crops with high plant densities requiring large amount of pipes per land unit. Even so, the system is most successful for high income crops, inspite of relatively high investment cost of most installations.

Advantages of Drip Irrigation System

There are several recognised advantages of drip system which are discussed below:

i) *Improved water penetration:* Application of water at slow rates to limited areas around plants improves water penetration even in problem soils.

ii) *Reduction of deleterious effects of salts:* Frequent or daily application of water keeps the salts present in the soil water more dilute and leaches them to outer limits of the wetting pattern making the use of saline water a practical proposition.

iii) *Water savings:* Because of a high degree of control being possible under this system of irrigation, water can be applied uniformly. Only that portion of the soil in which there are active roots need be irrigated, and evaporation losses can be reduced to a minimum. The low rate of application, which is often only slightly greater than the consumptive use rate, reduces deep seepage losses. It is seen that water savings upto 60 per cent are possible.

iv) *Crop response:* A high average soil water level, along with adequate soil air, can be maintained with this system. This results in a favourable response by some crops, with high yield and high quality of crops.

v) *Labour savings:* Most drip systems are permanent or semipermanent set-ups, and so have low labour requirements. They may also be automated to further reduce labour needs.

vi) *Optimum use of fertilizer:* Fertilizer can be applied through drip irrigation system using special equipment. Because of close control over the use of water, there is also a good control over fertilizer application resulting in savings. In addition, because of the small amount of water lost through deep seepage, the loss of fertilizer through leaching is minimized.

vii) *Less weed growth:* As only a fraction of soil surface is wetted in this system, there is a much reduced area available for weed growth. Thus, weed control is much less a problem than in other systems.

viii) *Early maturation:* Experiments on tomatoes, grapes and sugarbeets, to name but a few crops, have shown their significantly earlier maturation than is attained with other irrigation systems.

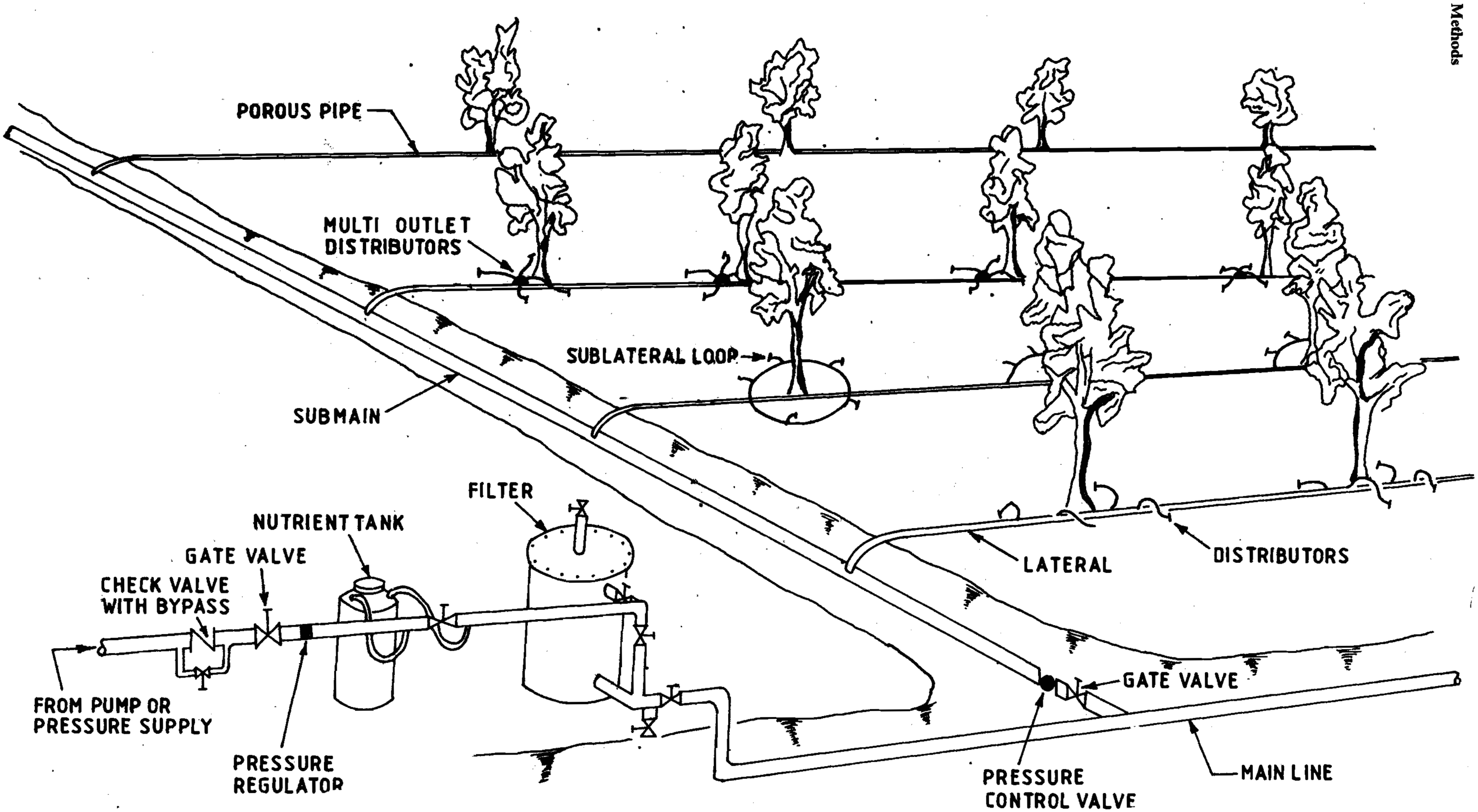


Figure 8.4 : Basic Components of a Drip Irrigation System

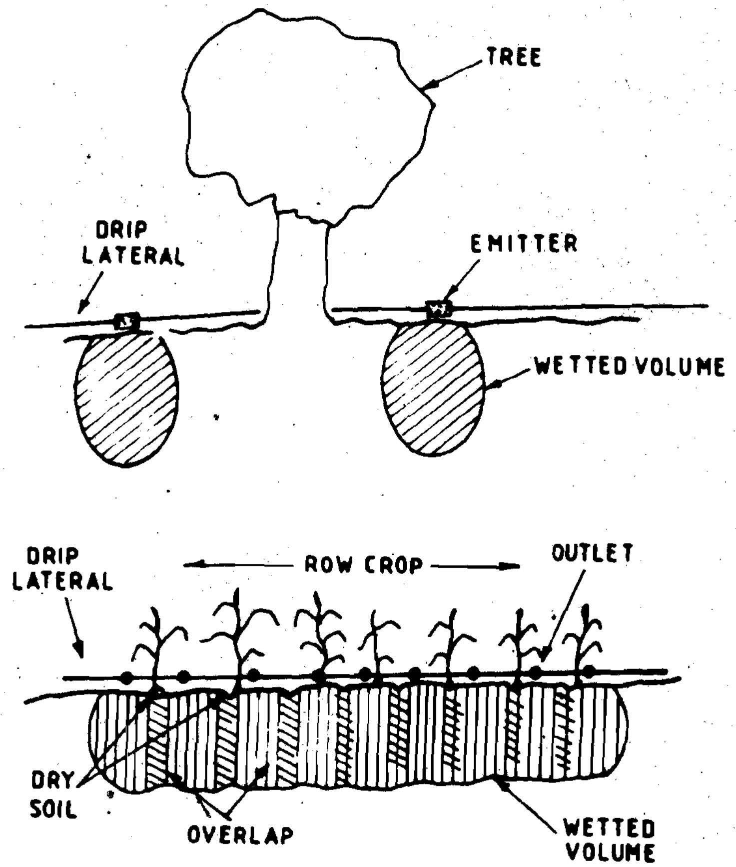


Figure 8.5: Drip Irrigation Soil Wetting Patterns

ix) *Minimization of soil crusting:* A significant problem in some soils concerns the formation of a hard surface crust. This can prevent emergence of a crop, even if it has germinated properly. By maintaining a constant high moisture content crusting can be eliminated.

x) *Field edge losses are reduced:* There is no loss at the edge of fields as can occur through wind drift of sprinkler systems or runoff from surface systems.

xi) *Improved root penetration:* In some soils, where root penetration is minimal or impossible at low water contents, the high average water content maintained with drip system alleviates this problem.

xii) *Field operation easier to manage:* When a drip system is properly managed the soil does not approach saturation as is the case with other irrigation systems. Thus, its ability to bear a load remains intact and so cultivation, harvesting, and other operations can be conducted during the application of irrigation itself.

Disadvantages of Drip Irrigation System

Like any other system, drip system also has certain disadvantages which are outlined below :

i) *Sensitivity to clogging:* The small openings used in many discharge mechanisms make them extremely sensitive to clogging. Salt and chemical deposits can accumulate at discharge openings causing them to become plugged.

ii) *Salinity hazards:* Although drip system can be used under saline conditions, it must be managed properly. Otherwise, reverse pressure gradients in the soil will cause flow of salts toward the plant roots with resulting detrimental effects.

iii) *Dry soil and dust formation during mechanical operations:* The fact that a large part of the soil surface may receive no water during irrigation can cause any village-wide operations to result in extreme break-up of the soil. This can result in dust problems and soil erosion during windy periods.

iv) *Requirement of skill:* High skill is required in the design, installation, operation and maintenance of a drip irrigation system.

8.3.1 Components of a Drip System

The basic components of a drip irrigation system are listed, as follows:

1) Pump and power unit,
2) Filters,
3) Distribution system,
4) Emission devices,
5) Control and monitoring equipment, and
6) Supplemental system.

The basic components of a drip irrigation system are depicted in Figure 8.4.

Pumps and Power Unit

The cost of pump and power unit represents a significant portion of the initial cost of the system. A centrifugal pump is best suited for the drip system; and a pump with a greater rated discharge capacity, at the desired operating head that can be discharged through emitters, is generally selected for use. At many places the distribution system is connected to the overhead tank to create the necessary head to maintain the desired flow.

Filters

Filters are required to remove sand and other organic suspended particles to prevent clogging of emitters. They cannot remove dissolved minerals, algae cells or bacteria. Sand filters are seen to effectively remove sand, silt and organic materials as well. It must be periodically back washed either manually or automatically, and periodic chemical treatment may be necessary to kill bacteria and algae. Cartridge filters may be either disposable or washable and are available in smaller sizes for smaller flow rate systems. They are useful when the sediment load is small; however, they cannot be used if algae is present in water.

The emitter orifice size and water quality determine the type of filter to be used. One rule of thumb is to select filters that retain all particles at least one tenth the diameter of smaller passage way. A clean well water source may only require 80-100 mesh filter. However, a 160 - 200 mesh screen is normally used to keep the particles small enough to pass through most of the filters. A secondary filter with 100 to 200 mesh screens should be installed at each lateral.

Distribution Lines

Water from a given pump may be carried to the edge of the field by a single large *main line*. From this mail line smaller lines (*submains* or *manifolds*) carry water to *lateral lines* from which it is applied to the plants through *emitters*. Rigid PVC pipes may be used for the main and submain lines. Normally 12mm polyethylene pipes are used for laterals.

Emission Devices

Emission devices available in the market may be grouped into three categories based on their operating principles, such as those that :

i) rely on head loss along a tube having a small diameter,

ii) have some form of orifice control, and

iii) dissipate the pressure energy through a vortex action.

Some set-ups do not have individual distributors but do have a vast number of tiny perforations along their entire length so that water leaks out all along the lateral. Some distributors are self compensating in that they can deliver approximately the same discharge over a wide range of pressure. Distributors may be inserted into the wall of the lateral (inserted distributors) or be an integral part of the lateral (in-line distributors). The most commonly used distributors are microtubes. These are the simplest, cheapest and forerunner of all distributors. It is a microtube which is a small bore black polythene tube of approximately 0.5 - 1.5mm internal diameter (Figure 8.6). The discharge from a microtube varies according to the operating pressure, diameter and length of the tube.

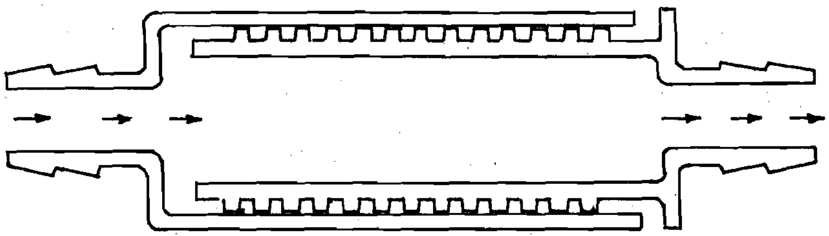


Figure 8.6: Enlarged View of a Line Distributor

Control and Monitoring Equipment

Flow Meters

Flow meters are particularly important to monitor the performance in order to manage permanent systems. Daily logging of flow to various sections allows discovery of problems before they became serious. A gradual decrease in flow may indicate clogged filter or emitters; and, a sudden increase may indicate a line break.

Pressure Gauges

Pressure gauges are recommended to check pressure throughout the system. They are specially important whe.. compensatory emitters are not used.

Vacuum Relief Valve

Negative pressures that develop when the system is turned off can clog emitters if dirty water is pulled back into the system. A vacuum relief valve, to avoid this problem, has to be installed downstream of the valve that controls the supply of water into the block.

Flush Valve

A flush valve at the end of each lateral allows flushing out the system.

Supplemental System

Fertilizer Application

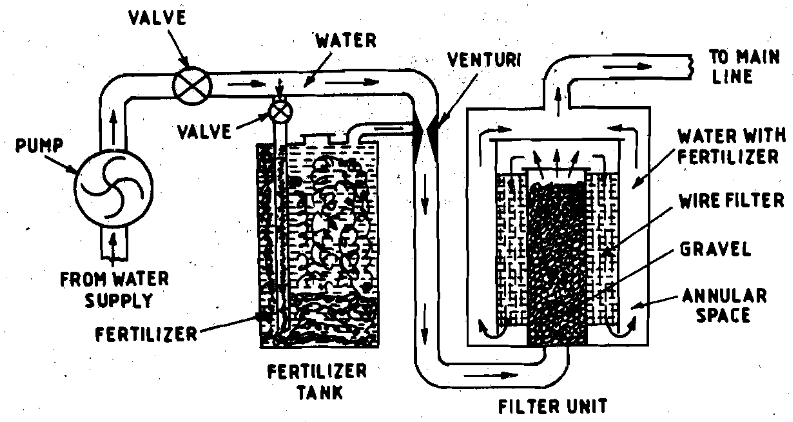
In drip irrigation soluble fertilizer can be applied to the plant root zone. If fertilizers are broadcast or otherwise applied to the soil separately, water from the emitters will not dissolve the nutrients as the water infiltrates directly into the soil. The soluble fertilizers can be introduced into the set-up by the following systems:

i) Fertilizer tanks or the pressure differential systems,

ii) Pump injectors.

Fertilizer Tanks

In a pressure differential system the pressure in the tank and in the mainline is the same, but it operates by the creation of slight pressure difference by a pressure reducing valve or a venturi tube as shown in Figure 8.7. The concentration of chemical injected into irrigation system mainline changes continuously with time.



6·5 cm

Figure 8.7: Arrangement of Pump, Fertilizer Tank, Filter Unit and Accessories Forming the Head of the Drip Irrigation System

Pump Injectors

Fertilizers can also be injected into an irrigation system by means of a pump. The rate of injection, and hence, the fertilizer concentration can be adjusted at will. However, this system is expensive.

8.3.2 Basic Data for the Design of Drip System

The first step in the design of an irrigation system is the acquisition of knowledge of crop water requirement. The crop water requirement is defined as the rate of evapotranspiration of a disease-free crop growing in a field, of not less than one hectare area, under optimum soil conditions.

The amount of evapotranspiration of a crop may be computed using the pan evaporimeter observations. The relationship may be expressed as follows:

$$ET_{crop} = K_p \times K_c \times E_{pan} \quad \ldots(8.5)$$

where, ET_{crop} = Evapotranspiration of the crop in mm/day,

ET_{pan} = Pan evaporation in mm/day,

K_p = Pan coefficient varying from 0.6 to 0.8, and

K_c = Crop coefficient (The crop coefficient for different crops and at different stages of growth is furnished in Table 8.5)

Drip irrigation is mainly used for orchard and row crops where the canopies of trees do not cover the entire area. As the crop water requirements determined by conventional methods include non-beneficial evaporation and transpiration, a reduction factor K_r should be applied. The reduction factor depends on the ground cover (GC). The value of K_r suggested by various authors are furnished in Table 8.6. Hence, the evapotranspiration requirement has to be modified as shown below:

$$ET_{crop} = K_p \times K_c \times K_r \times E_{pan} \quad \ldots(8.6)$$

Irrigation Water Requirements

The irrigation water requirement (IR) is the amount of water which must be supplied to the crop to ensure that it receives its full requirement after accounting for all the losses. The gross irrigation requirement (IR_g) may be expressed as:

$$IR_g = [IR_n / E_a] + LR \quad \ldots(8.7)$$

Table 8.5 : Crop Coefficient (K_c)

Crop	Crop Development Stages					Total Growing Period
	Initial	Crop Develop-ment	Mid Season	Late Season	At Harvest	
Banana *tropical* *subtropical*	 0.4-0.5 0.5-0.65	 0.7-0.85 0.8-0.9	 1.0-1.1 1.0-1.2	 0.9-1.0 1.0-1.15	 0.75-0.85 1.0-1.15	 0.7-0.8 0.85-0.95
Bean *green* *dry*	 0.3-0.4 0.3-0.4	 0.65-0.75 0.7-0.8	 0.95-1.05 1.05-1.20	 0.9-0.95 0.65-0.75	 0.85-0.95 0.25-0.3	 0.85-0.90 0.70-0.80
Cabbage	0.4-0.5	0.7-0.8	0.95-1.1	0.90-1.0	0.80-0.95	0.7-0.8
Cotton	0.4 - 0.5	0.7 -0.8	1.05 - 12.25	0.8 -0.9	0.65 - 0.7	0.8 -0.9
Grape	0.35 - 0.55	0.6 - 0.8	0.7 - 0.9	0.6 - 0.8	0.55 - 0.7	0.55 - 0.75
Groundnut	0.4 - 0.5	0.7 - 0.8	0.95 -1.1	0.75 - 0.85	0.55 - 0.6	0.75 -0.8
Maize *Sweet* *green*	 0.3 - 0.5 0.3 -0.5	 0.7 - 0.9 0.7 -0.85	 1.05 - 1.20 1.05 - 1.20	 1.0 - 1.10 0.8 - 0.95	 0.95 - 1.1 0.55 -0.6	 0.8 - 0.95 0.75 - 0.90
Onion *dry* *green*	 0.40 - 0.60 0.40 - 0.60	 0.70 - 0.80 0.60 - 0.75	 0.95 - 1.10 0.95 - 1.05	 0.85 - 0.90 0.95 - 1.05	 0.75 - 0.85 0.95 - 1.05	 0.80 - 0.90 0.65 - 0.80
Pea (*fresh*)	0.4 - 0.5	0.7 - 0.85	1.05 - 1.20	1.0 - 1.15	0.95 - 1.1	0.80 - 0.95
Pepper (*fresh*)	0.3 - 0.4	0.6 - 0.75	0.95 - 1.1	0.85 - 1.0	0.8 - 0.9	0.7 -0.8
Potato	0.4 - 0.5	0.7 - 0.8	1.05 - 1.2	0.85 - 0.95	0.7- 0.75	0.75 - 0.90
Rice	1.1 - 1.15	1.1 - 1.5	1.1 - 1.3	0.95 - 1.05	0.95 - 1.05	1.05 - 1.20
Sofflower	0.3 - 0.4	0.7 - 0.8	1.05 - 1.02	0.65 - 0.7	0.20 - 0.25	0.65 - 0.7
sorghum	0.3 - 0.4	0.70 - 0.75	1.0 - 1.15	0.75 - 0.8	0.5 - 0.55	0.75 - 0.85
Soyabean	0.3 - 0.4	0.7 - 0.80	1.0 - 1.15	0.70 - 0.80	0.4 - 0.5	0.75 - 0.90
Sugarbeet	0.4 - 0.5	0.75 - 0.85	1.05 - 1.20	0.09 - 1.0	0.6 - 0.70	0.8 - 0.90
Sugar cane	0.4 -0.5	0.7 -1.0	1.0 - 1.30	0.75 - 0.80	0.5 - 0.6	0.85 - 1.05
Sunflower	0.3 - 0.40	0.7 - 0.8	1.05 -1.20	0.7 - 0.80	0.35 - 0.45	0.75 - 0.85
Tobacco	0.3 - 0.4	0.7 - 0.8	1.0 - 1.20	0.9 - 1.00	0.75 - 0.85	0.85 - 0.95
Tomato	0.4 - 0.5	0.7 - 0.8	1.05 - 1.25	0.80 - 0.95	0.60 - 0.65	0.75 - 0.90
Watermelon	0.4 - 0.5	0.7 - 0.8	0.95 - 1.05	0.80 - 0.90	0.65 - 0.75	0.75 - 0.85
Wheat	0.3 - 0.4	0.7 - 0.8	1.05 - 1.20	0.65 - 0.75	0.20 - 0.25	0.8 - 0.90
Alfalfa	0.3 - 0.4				1.05 - 1.20	0.85 - 1.05
Circus (*Clean weeding*) (*No weed control*)						 0.65 - 0.75 0.85 - 0.90
Olive						0.4 - 0.6

where,

IR_n = Required depth of irrigation water excluding the contribution from other source, say, rainfall,

LR = Leaching requirement,

E_a = Application efficiency = $K_s K_u$,

K_s = Water storage efficiency of the soil (for coarse sand, or light top soil with gravel subsoil it is 87%; for sands 91%; for silts 95%; and for loam and clay 100%), and

K_u = Coefficient of application uniformity (<1).

Table 8.6 : Values of Kr, Suggested by Various Authors

Ground Cover GC (%)	K_r	K_r	Kr
	Keller & Karmeli	Freeman & Garzoli	Decroix Ctgref
10	0.12	0.10	0.20
20	0.24	0.20	0.30
30	0.35	0.30	0.40
40	0.47	0.40	0.50
50	0.59	0.75	0.60
60	0.70	0.80	0.70
70	0.82	0.85	0.80
80	0.94	0.90	0.90
90	1.00	0.95	1.00
100	1.00	1.00	1.00 (Values to be used in design)

The determination of pipe sizes, and capacity of a pump, etc., is to be done on the basis of peak irrigation requirment (PIR). The day to day irrigation requirement is met by adjusting the duration and/or frequency of irrigation and not by altering the flow rate on which the hydraulics of pipe network is based.

$$PIR_g = \frac{E_{pan}}{E_a} K_p K_c K_r + LR \qquad \text{... (8.8)}$$

where, suffix g refers to the gross quantity.

Water requirement of field crops and orchard crops are presented in Table 8.7 and 8.8.

Laterals

The out flow from each distributor is controlled by the pressure distribution along the laterals, while the pressure distribution is controlled by the energy drop due to friction and whether the pipe line is going up or down a slope.

Hazen William's formula is normally used for the design of plastic pipes. Friction loss in a pipe line with multiple outlets can be determined as in the case of Sprinkler Irrigation System design by first assuming the friction loss in the line without distributors, and then multiplying this loss by a factor, F, that depends on the number of outlets on the line. The pressure variation in the lateral should not exceed 10% and 20% for laminar and turbulent flow in distributors, respectively.

The average head for the lateral is the head for which the distributor flow rates are averaged. It has been proved that the average head occurs at 0.39 length of the lateral, and approximately 77 per cent of total head loss in the lateral occurs within this length. Therefore, the average head of a lateral may be expresed as:

$$\text{Average head, } H = \text{Head at inlet } (H_o) - 0.77H \qquad \text{...(8.9)}$$

When the terrain has a fairly uniform slope, the head difference is characterised by linear loss/gain curve. If the land is undulating it is represented by a nonlinear variation.

Table 8.7: Water Requirement of Different Crops

S.No.	Name of the Crop	WR (cm)	No. of Irrigation	Effective Root Zone Depth, (cm)
1	Wheat	45	5 to 7	90
2	Pea	15	1 to 2	90
3	Potato	50	8 to 10	60
4	Rice	120	8 to 10	60
5	Sorghum (Kharif)	45	4	100
6	Sorghum (Rabi)	40	3	100
7	Pearl millet	30	2	100
8	Maize (Kharif)	40	4	120
9	Groundnut (Kharif)	45	3	90
10	Groundnut (Summer)	80	12	90
11	Sunflower	30	4	90
12	Safflower	30	2	120
13	Gram	25	2	60
14	Cotton	80	10	120
15	Sugarcane (Suru)	250	32	90
16	Sugarcane (Adsali)	300	38	90
17	Chili	60	10	90
18	Bitter gourd	45	10	120
19	Ridge gournd	50	13	120
20	Onion (Summer)	75	13	60
21	Brinjal (Summer)	90	55	75
22	Tomato	35	5	70

Source : 1. Krishidarshani, MPAU, Rahuri, 1987
2. Irrigation, Theory and Practice A.M,Michel

Table 8.8: Water Requirement of Different Crops in Litres

S.No.	Crop	Spacing between crop (m^2)	Evaporation, (mm/day)						
1	2	3	4	6	8	10	12	14	16
	Chuku, Mango	10×10	86.4	129.0	172.9	216.1	259.1	302.5	345.7
2	Coconut	7×7	41.9	62.9	83.9	104.9	125.9	146.9	167.9
3	Guava, Citrus	6×6	50.0	75.1	100.1	125.1	150.2	175.2	200.3
4	Pommegranate, Lamon, Sitaphal	5×5	20.3	30.4	40.6	50.8	60.9	71.1	81.2
5	Panmala	3×0.3	0.79	1.17	1.57	1.16	2.35	2.75	3.14
6	Grapes Grapes	3×1.6 2×12	3.97 1.9	5.95 2.1	7.93 3.87	9.91 4.76	11.90 5.71	11.88 6.66	15.86 7.62
7	Banana	1.5×1.5	1.98	2.97	3.96	4.95	5.95	6.94	7.93
8	Sugarcane	1.0×4.3	0.24	0.36	0.48	0.60	0.72	0.84	0.96
9	Cotton	1.3×1.3	1.27	1.90	2.54	3.17	3.8	4.44	5.08
10	Tomato, Chilli, Brinjal	1.0×0.5	0.36	0.54	0.72	0.09	0.08	1.27	1.45

Example 8.1

In an orchard (in a sandy soil) trees are planted at 5m interval, and it is estimated to have the canopy cover of 75 per cent. The monthly average pan evaporation is 6.3 mm/day. The pan coefficient and crop coefficient may be assumed as 0.70 and 1.15, respectively. If the coeficient of application uniformity is 0.90, determine the number of drippers required and the number of hours they have to be operated.

Solution

Monthly pan evaporation, E_{pan} = 6.3 mm /day

Pan coefficient, K_p = 0.70

Crop coefficient, K_c = 1.15

Ground cover (GC) = 75%

Reduction factor, K_r, for 75% GC from Table 8.6

= 0.85 (last column of the Table)

Type of soil : Sandy

Water storage efficiency for sandy

soil, $K_s = 0.91$

Application efficiency = $E_a = K_s E_u$

Uniformity of application = $E_u = 0.90$

$\therefore E_a = 0.91 \times 0.90 = 0.819 \simeq 0.82$

Peak irrigation requirement, $PIR_g = \frac{E_{pan}}{E_a} K_p K_c K_r$ (LR being zero)

$$PIR_g = \frac{6.3 \times 0.70 \times 1.15 \times 0.85}{0.82} = 5.257 \text{ mm/day}$$

Spacing of plants = 5m × 5m (given)

Peak irrigation requirement of a plant, $I = PIR_g \times A$

$$= 5.3 \times 5 \times 5 = 132.50 \; l\,/\,\text{day/plant}$$

Selecting the emitter of a capacity of 4 lph, and operating the system for 12 hours we have:

Number of emitters required (per distributor) $= \frac{132.50}{4 \times 12} = 2.76$ or, say, 3

Therefore, number of hours of operation $= \frac{132.5}{4 \times 3} = 11$ hours

Example 8.2

Find the pressure distribution in a lateral of 150m length. Use the data given in Example (8.1). The lateral may be designed for various cases, such as, the lateral running on flat, up-hill and down-hill slopes.

Solution

Length of the lateral	=	150m
Spacing of plant	=	5m × 5m
∴ Number of distributors	=	$\frac{150}{5} = 30$
Number of emitters in a distributor	=	3
Discharge rate of the emitter	=	4 lph
The lateral flow rate	=	$30 \times 3 \times 4 = 360$ l/hr
	=	0.10 lps
Supply head	=	15m (assumed)

The pressure loss and the pressure available at the inlet and plug end of the lateral for the flat, up hill and down hill slope conditions are worked out and furnished in the Table 8.9.

Length of Lateral - 150 m
No. of emitters - 3 × 30 = 90
Spacing of plant - 5 m × 5 m

Table 8.9: Lateral Design – Drip System (Example 8.2)

ID of pipe (mm)	Head loss at full flow (m/100 m)	Length of lateral (m)	Reduction factor (F)	Head loss (H_f)	Av. pr in the lateral (H)	Loss/gain of head due to ground slope (Hs)			Total pressure at inlet A + 0.77 H_f 0.39 Hs			Total pressure of end of lateral H–0.23 H_f 0.61 Hs			Pressure difference (8) - (9) percentage		
						Flat	0.5% Down	0.5% up	Flat	D/S	U/S	Flat	D/S	U/S	Flat	D/S	U/S
(1)	(2)	(3)	(4)	(5)	(6)	(7a)	(7b)	(7c)	(8a)	(8b)	(8c)	(9a)	(9b)	(9c)	(10a)	(10b)	(10c)
12.8	7.5	150	0.357	4.02	15.00	0.00	0.75	-0.75	18.10	17.81	18.39	14.08	14.54	13.62	22.2	18.36	25.93
16.4	2.0	150	0.357	1.07	15.00	0.00	0.75	-0.75	16.82	15.53	16.11	14.75	15.21	14.29	6.76	2.06	11.30
20.8	0.7	150	0.357	0.374	15.00	0.00	0.75	-0.75	15.29	15.00	15.58	14.91	15.37	14.45	2.49	+2.47	7.25

Note:

As the permissible pressure variation between the inlet of lateral and its end should be less than 10%. the pipe of 16.4 mm dia can be used in flat and down slope alignment; while it is not suitable if it is taken upslope. The pipe 20.8 mm dia can be used in all conditions.

8.5 KEY WORDS

Mobile Raingun : A type of sprinkler.

Pressurised Irrigation : A system of irrigation in which water in applied through pressure devices and flow is essentially through pipes. Sprinkler and Drip irrigation systems fall under this category.

Sip Irrigation : Drip Irrigation.

Sprinkler Head : A component of sprinkler irrigation system.

Crop Water Requirement : Rate of evapotranspiration of a disease free crop growing in a field, of not less than one hectare area, under optimum soil conditions.

8.4 SUMMARY

Sprinkler and drip irrigation together constitute the pressurised irrigation system. These methods of irrigation are best suited for water-scarcity zones. Both these methods contribute to the reduction of loss of water through surface runoff, evaporation during conveyance, and deep percolation. Also distribution of fertilizers through the pipe lines comprising these two systems is achieved to a high degree of efficiency with ease.

There are various types of sprinkler systems available for use depending upon the requirements in the field. Basic design considerations that are relevant include: requirement of water and frequency of appplication, capacity of the system, number of sprinklers(or emitters) needed and their spacing, loss due to friction and layout of this system (sprinkler or drip).

8.6 ANSWERS TO SAQs

SAQ 1

Given Q = 25 lit/min $= \dfrac{25}{60} \dfrac{lit}{sec} = 0.417\ l/s$

$S_1 = 15$ m $S_2 = 18$ m

Application rate $= \dfrac{360 \times q}{S_1\, S_2}$

$$= \frac{360 \times 0.4167}{15 \times 18}$$

$$= 1.25 \text{ cm/hr}$$

This application rate should be compared with the infiltration rate of the soil and whichever is minimum is to be taken as the application rate.

Also the application rate of sprinkler (individual)

$$= \frac{360 \times q}{wetted\ area}$$

$$= \frac{360 \times 0.417}{\frac{\pi}{4} \times (30)^2}$$

$$= 0.212 \text{ cm/hr} = 2.12 \text{ mm/hr}$$

SAQ 2

Application rate $= \dfrac{360\ Q}{L\ S}$

Where Q = discharge in lit/s

L = length of lateral

S = Spacing of lateral

$$= \frac{360(^{500}/_{60})}{300 \times 15}$$

$$= 0.666 \text{ cm/hr}$$

Application rate = 6.67 mm/hr

SAQ 3

Length = 300 m

Spacing = 15 × 15 m

A = 25 ha

TR = 7 mm/day

ID = 15 mm

The time interval between successive irrigation

I_t = Desired maximum depth of water at each irrigation/ peak consumption

= 15/7 = 2.14 day

I_t = 2 days

SAQ 4

The system requirement

Q = lit/sec

A = 25 ha

E = 80%

H = 8 hrs

F = 2 days

D = 1.5 cm

Q = A . D . 27.8 / F . H . E

Substituting the values

$$Q = \frac{25 \times 1.5 \times 27.8}{2 \times 8 \times {}^{80}/_{100}}$$

Q = 81.44 lit/sec