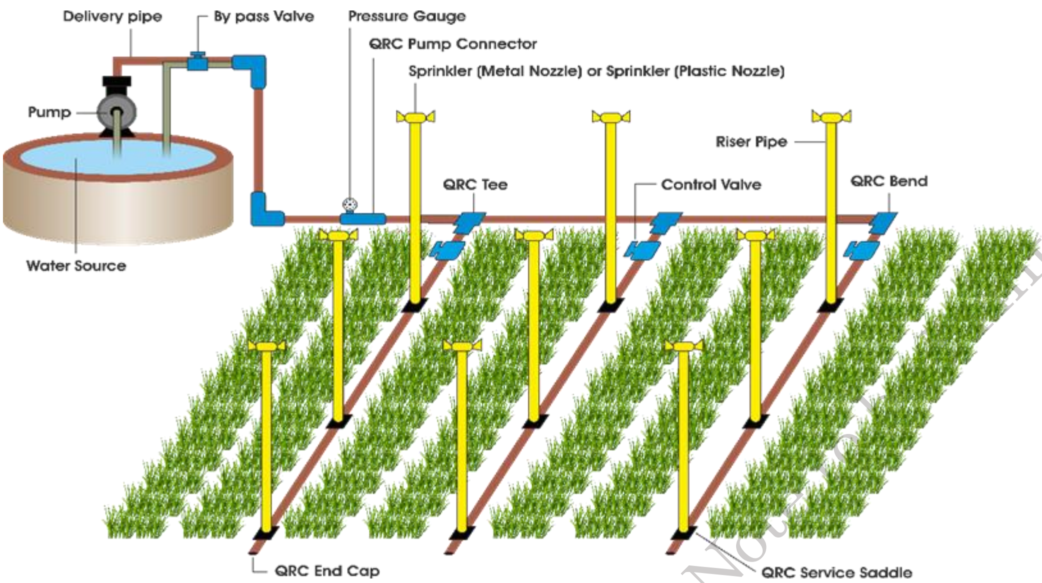
Draft Study Material



IRRIGATION SERVICE TECHNICIAN

(Qualification Pack: Ref. Id. AGR/Q1104)

Sector: Agriculture

(Grade XII)

PSS CENTRAL INSTITUTE OF VOCATIONAL EDUCATION
(a constituent unit of NCERT, under Ministry of Education, Government of India)
Shyamla Hills, Bhopal- 462 002, M.P., India
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Preface

Vocational Education is a dynamic and evolving field, and ensuring that every student has access to quality learning materials is of paramount importance. The journey of the PSS Central Institute of Vocational Education (PSSCIVE) toward producing comprehensive and inclusive study material is rigorous and time-consuming, requiring thorough research, expert consultation, and publication by the National Council of Educational Research and Training (NCERT). However, the absence of finalized study material should not impede the educational progress of our students. In response to this necessity, we present the draft study material, a provisional yet comprehensive guide, designed to bridge the gap between teaching and learning, until the official version of the study material is made available by the NCERT. The draft study material provides a structured and accessible set of materials for teachers and students to utilize in the interim period. The content is aligned with the prescribed curriculum to ensure that students remain on track with their learning objectives.

The contents of the modules are curated to provide continuity in education and maintain the momentum of teaching-learning in vocational education. It encompasses essential concepts and skills aligned with the curriculum and educational standards. We extend our gratitude to the academicians, vocational educators, subject matter experts, industry experts, academic consultants, and all other people who contributed their expertise and insights to the creation of the draft study material.

Teachers are encouraged to use the draft modules of the study material as a guide and supplement their teaching with additional resources and activities that cater to their students' unique learning styles and needs. Collaboration and feedback are vital; therefore, we welcome suggestions for improvement, especially by the teachers, in improving upon the content of the study material.

Deepak Paliwal
(Joint Director)
PSSCIVE, Bhopal

Date: 20 June 2024

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Module 1 | Irrigation Scheduling

Module Overview

This module focuses on the fundamental concepts and practices of irrigation management. It introduces learners to key topics such as the basics of irrigation, the importance of scheduling, and the calculation of irrigation requirements. Learners will explore techniques for measuring soil moisture, understand the implications of soil moisture stress, and learn about deficit irrigation strategies to optimize water use. This module equips students with essential knowledge to manage water resources effectively for agricultural sustainability.

Learning Outcomes

After completing this module, you will be able to:

- Understand the basic principles and significance of irrigation scheduling.
- Calculate net and gross irrigation requirements for crops.
- Analyse the importance of irrigation frequency and irrigation period in effective water management.
- Identify and apply various soil moisture measurement techniques.
- Evaluate the effects of soil moisture stress on crop growth.
- Implement deficit irrigation strategies to conserve water while maintaining crop productivity.

Module Structure

1.1. Introduction
1.2. Irrigation scheduling and its importance
1.3. Net and Gross Irrigation Requirement
1.4. Irrigation Frequency and Irrigation Period
1.5. Soil Moisture Measurement Techniques
1.6. Soil Moisture Stress and Deficit Irrigation

1.1 Introduction

Irrigation is defined as the science of artificially providing water to the land in accordance with the "crop requirement" throughout the "crop period" for the complete nourishment of the plant.

Irrigation scheduling is the process by which an irrigator determines the timing and quantity of water to be applied to the crop or pasture. The challenge is to estimate crop water requirements for different growth stages and climatic conditions.

The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. Although the values for crop evapotranspiration and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. The irrigation water requirement basically represents the difference between the crop water requirement and effective precipitation. The irrigation water requirement also includes additional water for leaching of salts and to compensate for non-uniformity of water application.

Evaporation: The transformation of water from liquid to gas or vapour is known as evaporation. Evaporation is the most common mechanism for liquid water to return to the water cycle as atmospheric water vapour.

When a liquid substance turns into a gas, it is called evaporation. Water evaporates when it is heated. Because the molecules travel and vibrate so quickly, they escape into the atmosphere as water vapour molecules.

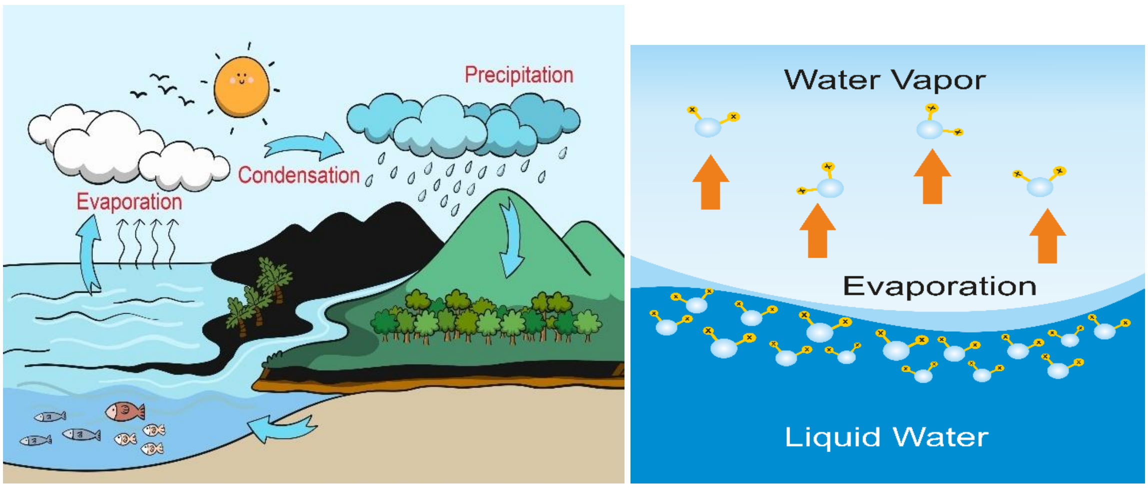


Fig 1.1: Evaporation

Transpiration: Water movement through a plant and evaporation from aerial portions such as leaves, stems, and flowers is known as transpiration. Water is absorbed from the soil by roots and transferred to the leaves via xylem as a liquid. Small pores in the leaves allow water to escape as vapour.

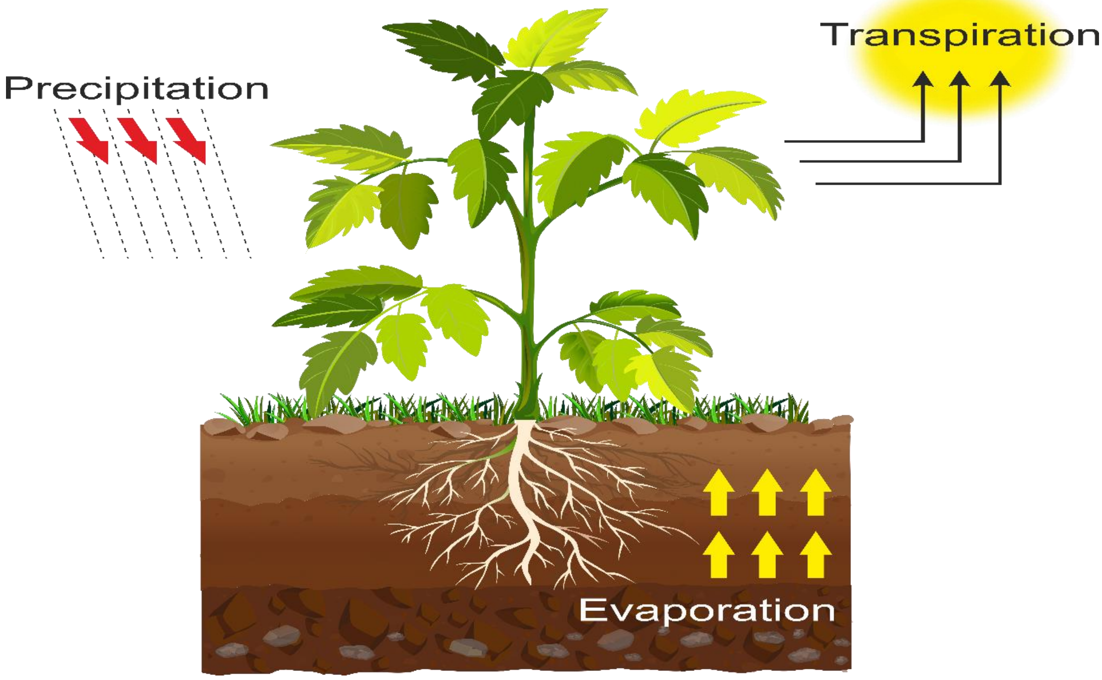


Fig.1.2: Transpiration

Evapotranspiration: Evapotranspiration (ET) is the sum of water evaporation and transpiration from a surface area to the atmosphere. The flow of water to the air from sources like soil, canopy interception, and water bodies is accounted for by evaporation.

The evapotranspiration rate is normally expressed in millimetres (mm) per unit of time. The rate expresses the amount of water lost from a cropped surface in units of water depth. The time unit can be an hour, day, month, or even an entire growing period or year.

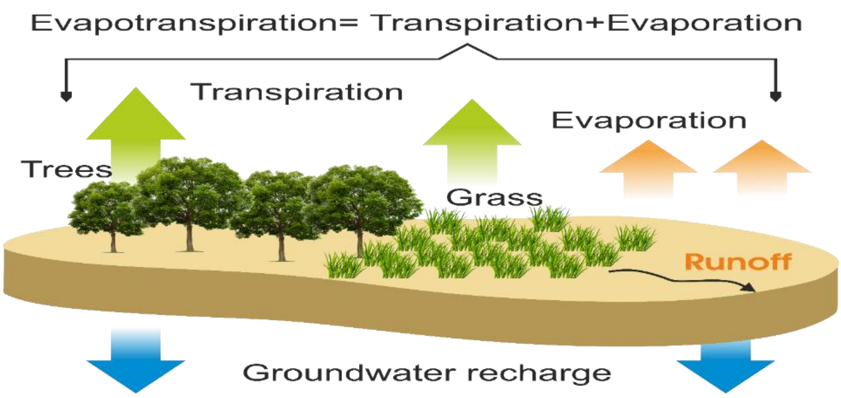


Fig. 1.3: Evapotranspiration

Consumptive use: Consumptive use refers to the amount of water utilised for a beneficial purpose that does not return to the groundwater or surface water source, such as water transpired by growing vegetation, evaporated from soils or water surfaces, or integrated into goods.

During crop growth, "Consumptive use" refers to the amount of water lost to evaporation as well as water absorbed into the plant through the roots and transpired through the leaves.

1.2 Irrigation scheduling and its importance

'Irrigation scheduling' is the decision of when and how much water to apply in the field crop. Its main purpose is to maximize irrigation efficiencies by applying the exact amount of water needed and replenishing the soil moisture at the desired level. It also saves water and energy.

In other words, Irrigation scheduling ensures that water is applied according to crop water requirements and is consistently available to the plant roots. To improve plant growth and to achieve high yield and/or quality, irrigation scheduling seeks to provide plants with appropriate quantities of water at appropriate times.

Proper irrigation scheduling will enhance the profitability by:

- Maximizing crop yield and quality
- Decreasing water loss through deep percolation and runoff
- Optimizing pumping and its cost
- Improving water use efficiency

To effectively schedule irrigation applications to the plants, the following important aspects need to be properly understood:

- Soil properties and its types
- Water holding capacity of the soils
- Soil moisture content
- Crop water use at the specific development stage
- Method of Irrigation

Another factor that needs to be considered within an irrigation scheduling programme is the depletion of available soil moisture for the specific crop. This is the percentage of available soil moisture that can be utilized before the occurrence of moisture stress. The capacity of the irrigation system should also be considered because, for scheduling purposes, it is important to know how much water the system can apply in a given duration of time.

1.3 Net and Gross Irrigation Requirement

A. Net irrigation requirement (NIR): Net irrigation requirement is the depth of irrigation water, exclusive of precipitation, carry-over soil moisture or groundwater contribution or other gains in soil moisture, that is required consumptively for crop production. Net irrigation requirement is the amount of irrigation water required theoretically to bring the soil moisture content to the level of field capacity in the root zone depth of the crops. Thus, the net irrigation requirement is the difference between

the soil moisture at field capacity (FC) and the soil moisture content in the root zone prior to the application (actual) of the irrigation water.
This may be obtained by the relationship given below:

$$IRn = \sum_{i=1}^{n} \left(\frac{Mfci - Mbi}{100} \right) * Ai * Di$$

Where,
IR_n = Net irrigation requirement (net amount of water to be applied during irrigation), cm
Mfc_i = Field capacity moisture content (percent by weight) in the i^{th} layer of the soil
Mb_i = Moisture content before irrigation in the i^{th} layer of the soil, %
A_i = Bulk density of the soil in i^{th} layer
D_i = Depth of the i^{th} soil layer, cm, within the root zone
n = Number of soil layers in the root zone

B. Gross irrigation requirement (GIR): The total amount of water applied through irrigation is termed gross irrigation requirement. In other words, it is the net irrigation requirement plus the losses in water application including other losses. The gross irrigation requirement can be determined for a field, a farm, for an area, or an irrigation project, depending on the need, by considering the appropriate losses at various stages of the crop.

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

The gross irrigation requirement at the field head can be determined as follows:

$$\text{Gross irrigation requirement (at field head)} = \sum_{i=1}^{n} \left(\frac{d}{Ea} \right)$$

Where,
GIR = Seasonal gross irrigation requirement at the field head, cm
d = Net amount of water to be applied at each irrigation, cm
E_a= Water application efficiency (fraction),
n = Number of irrigations in the season

1.4. Irrigation Frequency and Irrigation Period

A. Irrigation frequency: Irrigation frequency refers to the number of days between two successive irrigations during periods without rainfall. It depends on the consumptive use, and the amount of available moisture in the crop root zone. For the design of irrigation systems, the irrigation frequency to be used is the time (in days) between two irrigations for the period of highest consumptive use of the crops grown. The irrigation frequency may be computed as follows:

$$\textbf{Irrigation frequency (days)} = \frac{\text{FC of soil in effective crop root zone} - \text{Moisture content of the same root zone at the time of starting irrigation}}{\text{Peak period consumptive use}}$$

B. Irrigation period: The irrigation period is the number of days that can be allowed for applying one irrigation to a given design area during the peak consumptive use period of the crop being irrigated. The irrigation system must be so designed that the irrigation period is not greater than the irrigation frequency.

$$\textbf{Irrigation period} = \frac{\text{Net amount of moisture in the soil between start of irrigation and lower limit of moisture depletion}}{\text{Peak period consumptive use}}$$

1.5 Soil Moisture Measurement Techniques

1.5.1 Soil moisture content

Soil serves as a reservoir of water for the use of plants. Measuring soil moisture benefits the irrigation water management. Soil moisture is expressed as percentage of moisture present in the soil on weight basis or volume basis, e.g., when soil is stated to contain 10% moisture on a dry weight basis, it means 100 g of dry soil holds 10 g of water. Similarly, when expressed on volume basis, it means 100 cubic metre of soil holds 10 cubic metre of water. The moisture percentage is generally expressed on weight basis. The moisture percentage on weight basis (Pw) can be converted on volume basis (rhov ρ), if bulk density (BD) of soil is known.

1.5.2. Soil moisture measurement techniques

Soil moisture can be estimated by the direct and indirect methods. Direct methods involve the measurement of moisture in the soil, while indirect methods estimate the moisture content based on other properties of the soil. Indirect estimation of moisture present in the soil is most commonly done by the instruments like tensiometer, gypsum block, neutron probe, pressure plate, and pressure membrane apparatus.

A. **Direct method**

1. **Gravimetric method/Oven drying method:** The soil sample is collected in a moisture cane and took the weight of the wet sample is recorded (Fig. 1.4). The soil sample is dried in a hot air oven (Fig. 1.5) at 105^{0}C until a constant weight (normally 24 hours) is obtained and the dry weight of the sample is recorded (Fig. 1.6). This method is the classical procedure used as the check for all other methods.

$$\text{Moisture Content (wet basis) MCwb} = \frac{(\text{Moisture Content dry basis (MCdb)})}{\text{Moisture content dry basis} + 1}$$

$$\text{Moisture Content (dry basis) MCdb} = \frac{(\text{Moisture Content wet basis (MCwb)})}{1 - \text{Moisture Content wet basis}}$$

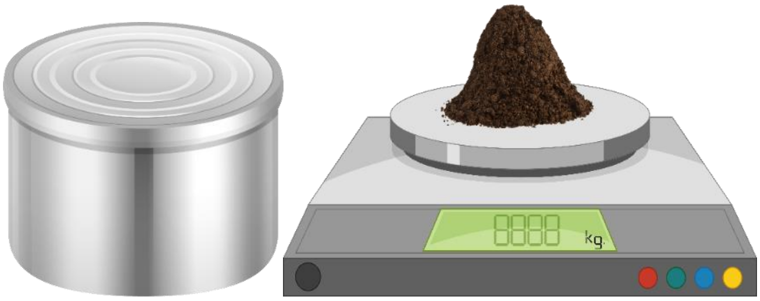


Fig. 1.4: Moisture can/cup with soil and measurement

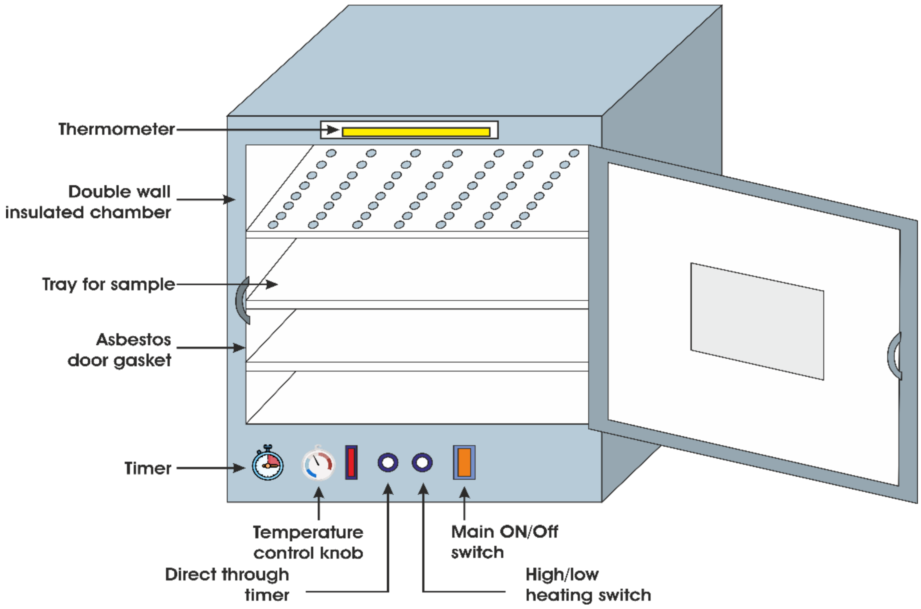


Fig. 1.5: Hot air oven

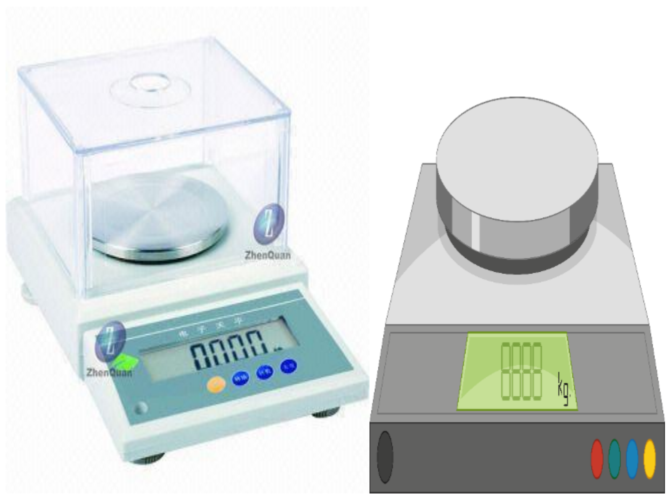


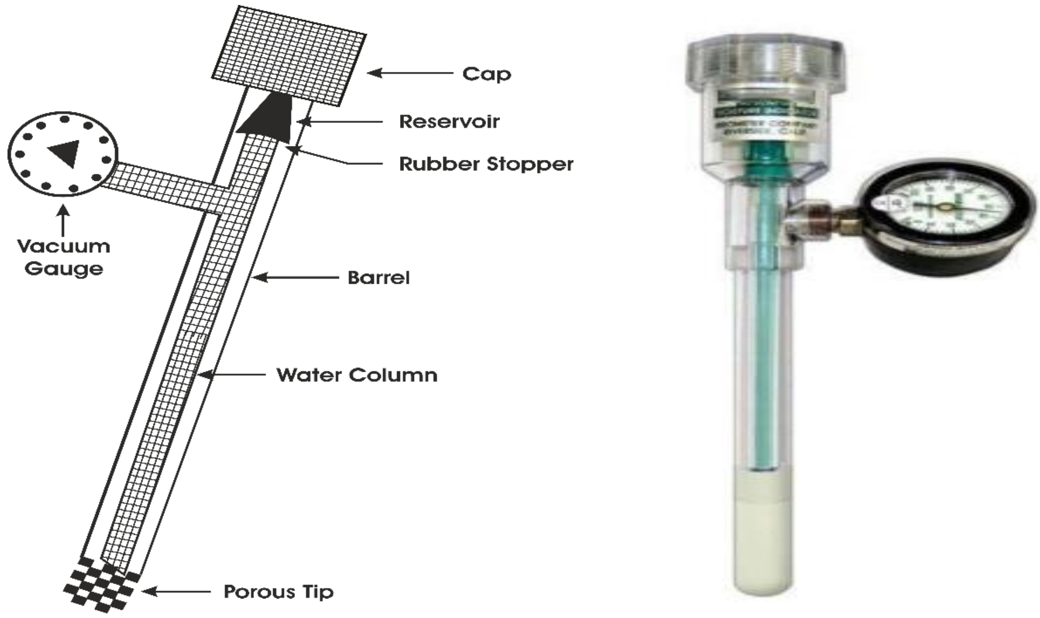
Fig. 1.6: Picture of weighing balance

2. **Volumetric method:** Soil sample is taken with a core sample or with a tube auger whose volume is known. The amount of water present in the soil sample is estimated by drying in the oven. The volumetric moisture content can also be estimated from the moisture content estimated on a dry weight basis.

B. Indirect Method

1. **Tensiometer method:** Tensiometers measure the matric potential of soil moisture *in-situ* (field). It consists of a porous ceramic cup attached to a tube filled with water and installed in the soil at the desired depth [Fig. 1.7 (A) and (B)]. The tube is attached to a vacuum gauge or a mercury manometer. As the soil dries, water moves out through the porous cup to maintain equilibrium. This creates a suction or vacuum on the water column. These suction readings are then calibrated on the gauge as soil moisture tension to a specific soil which estimates the percent of moisture.

   The main limitation of tensiometers is that they do not measure soil matric potential values for low moisture content generally close to wilting percentage. The actual range of effective measurement is only from 0 to -0.85 bars. Tensiometer is useful for measuring moisture in sandy soils than that of clay soils, because of lower matric potentials in the former soils.



(A) (B)

Fig.1.7: (A) and (B) Tensiometer

2. **Electrical resistance method:** This method is based upon the changes in electrical resistivity with the variation in soil moisture (Fig. 1.8). A gypsum block with two electrodes inside at a definite distance apart are used. Blocks of other

material can also be used like nylon, ceramic etc. These gypsum blocks require calibration for uniformity before use. The blocks are buried in the soil at the desired depth and the conductivity is measured with a modified Wheatstone bridge. Through this method, the percentage of moisture is correlated to the electrical resistance (ohm). Moisture content can be easily estimated between the field capacity and the wilting percentage by this method.

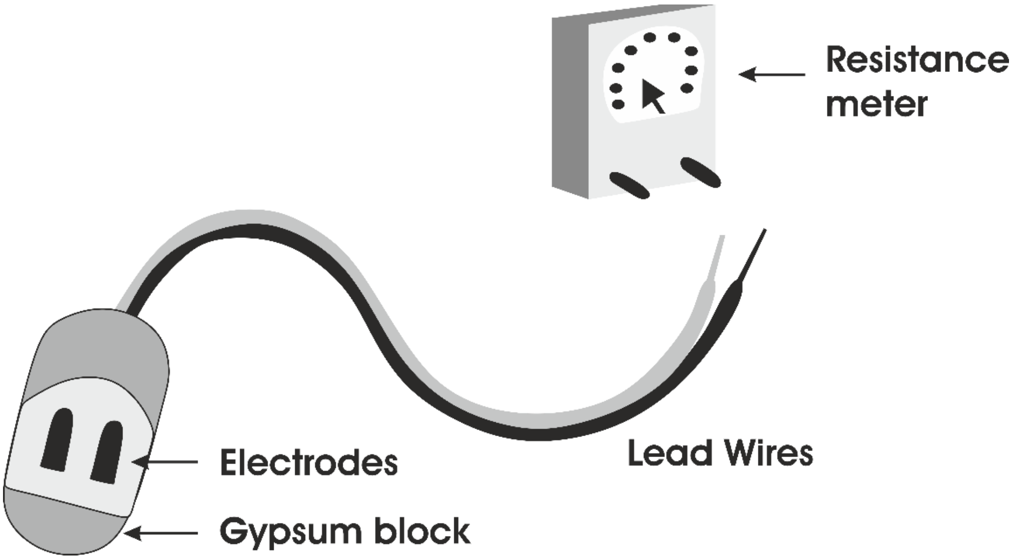


Fig.1.8: Gypsum block instrument

The limitation of this method is that it cannot be used in soils containing high salt concentration which interferes during the measurement.

3. **Neutron Scattering Method:** Neutron moisture meter (Fig. 1.9) is used for estimation of moisture present in the soil using neutron scattering method.

Neutron probes contain radioactive material consisting of the source of fast-moving neutrons (radium or beryllium) and a counter detector of slow-moving neutrons.

As the neutrons emitted from the probe collide with hydrogen ions (of which water is a major source), they are slowed and deflected, and some of the slowed deflected neutrons are deflected back to the probe were a counter measure them. Only slowed neutrons are counted. The more slowed neutrons that return (indicating a large number of collisions), the greater the water content of the soil.

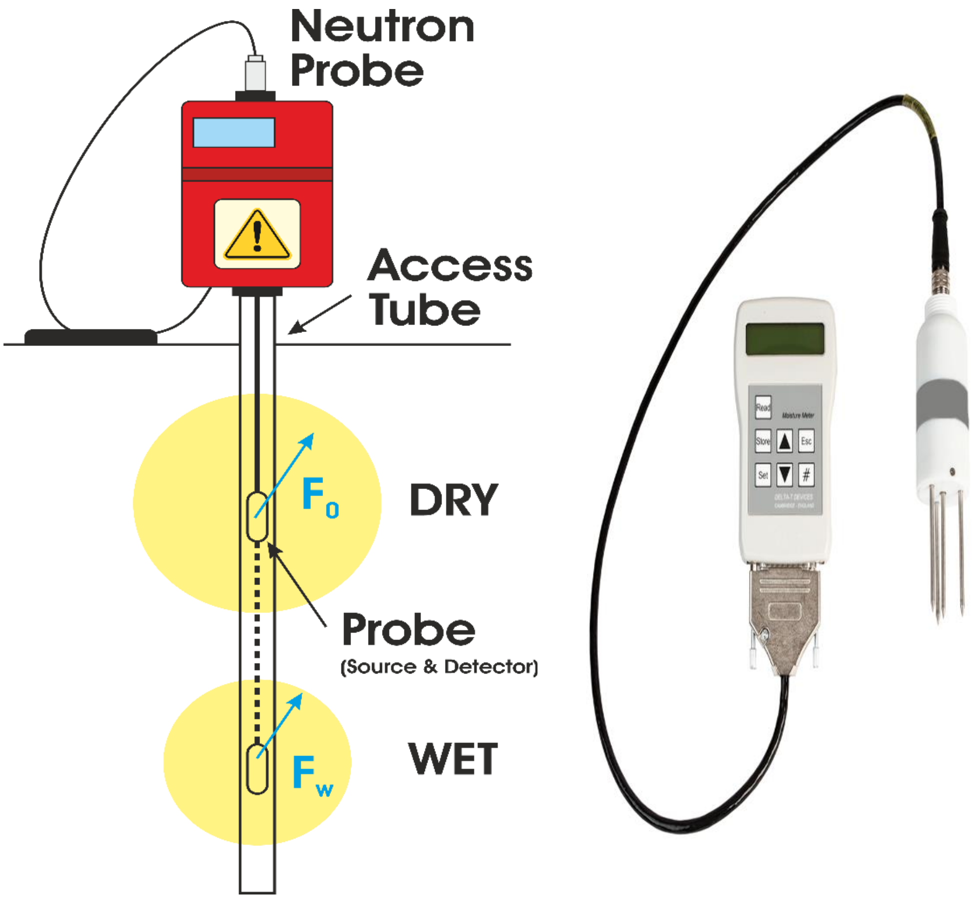
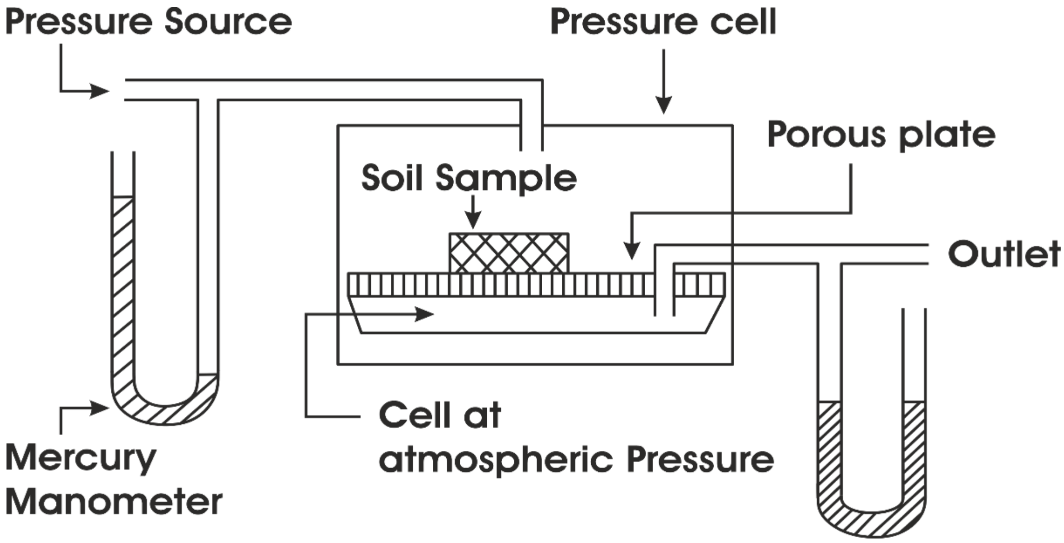


Fig.1.9: Neutron moisture meter

4. **Pressure Membrane and Plate Technique:**
   Laboratory measurements of soil moisture potential are usually made with pressure membrane and pressure (suction) plate equipment (Fig. 1.10). It consists of ceramic pressure plates or membranes of high air entry values contained in airtight metallic chambers strong enough to withstand high-pressure (15 bars or more). The apparatus enables the development of soil moisture characteristic curves in the higher range of matric potential (> 1 bar), which is not possible on suction plates.

The porous plates are first saturated and then the soil samples are placed on these plates. Soil samples are saturated with water and transferred to the metallic chambers. The chamber is closed with special wrenches to tighten the nuts and bolts with the required torque for sealing it.



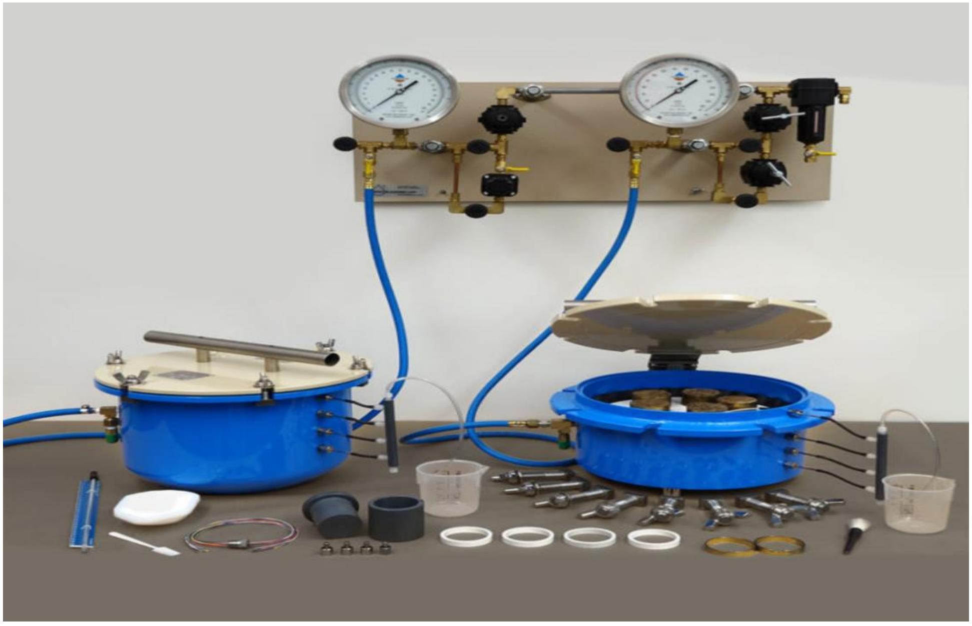


Fig.1.10: Pressure plate apparatus

The pressure is applied from a compressor and maintained at the desired level. It should be ensured that there is no leakage from the chamber. Water starts to flow out from saturated soil samples through the outlet and continues to trickle until equilibrium against the applied pressure is achieved.

The soil samples are taken out and oven dried to compute the moisture content and correlated with chosen values of pressure like 1/10, 1/3, 1, 5 and 15 bars. The soil moisture characteristics curves may be drawn for different values of soil moisture and pressure.

Other Techniques

Time Domain Reflector (TDR): A TDR sensor is used to determine moisture content in the soil, as well as porous media, both in the laboratory and in agricultural land. It is an electronic device that works on the principle of radar based on transmitting signals into the medium (Fig. 1.11) and collecting reflected signals. Analysis of reflected signals, particularly their magnitude, shape, and sign, provides a complete image of the transmitting medium. The reflections are measured, generally plotted as a function of time or sometimes as a function of cable length. TDR determines the dielectric constant and consequently permittivity and water content (direct related) of the medium, which is soil, via wave propagation transmitted by two parallel embedded metal probes with the utmost accuracy. The probes have a length of 10–30 cm, which is connected to the TDR via a coaxial cable.

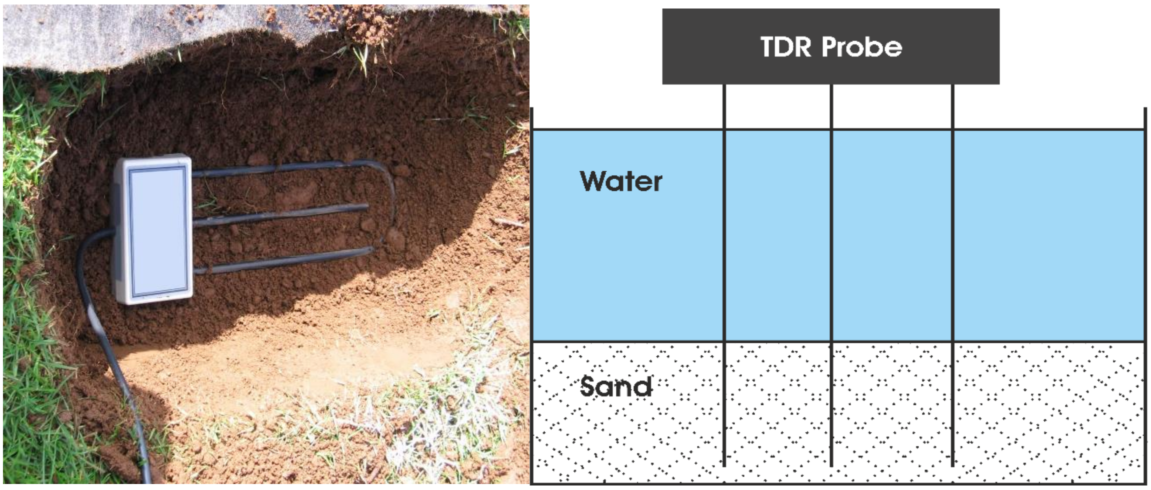


Fig. 1.11: Time Domain Reflector (TDR)

Frequency domain reflectometry: This uses the soil as a capacitor to measure the maximum resonant frequency in the electrical circuit and relate the resonant frequency to water content (Fig. 1.12).

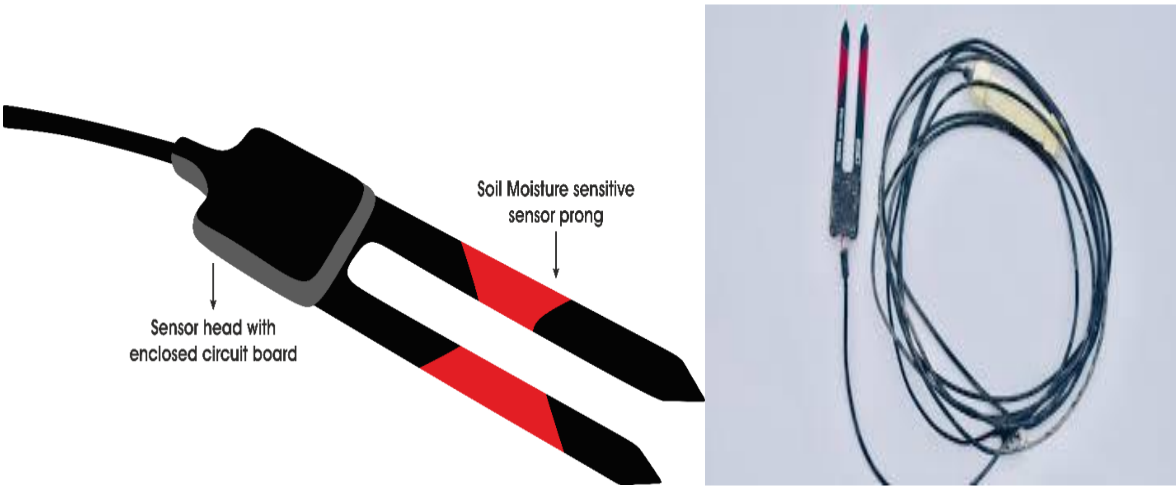


Fig. 1.12: Frequency domain reflectometry

Capacitance-based moisture measurement: A capacitance sensor uses the soil as a capacitor element and use the soil charge storing capacity to calibrate to water content (Fig. 1.13).

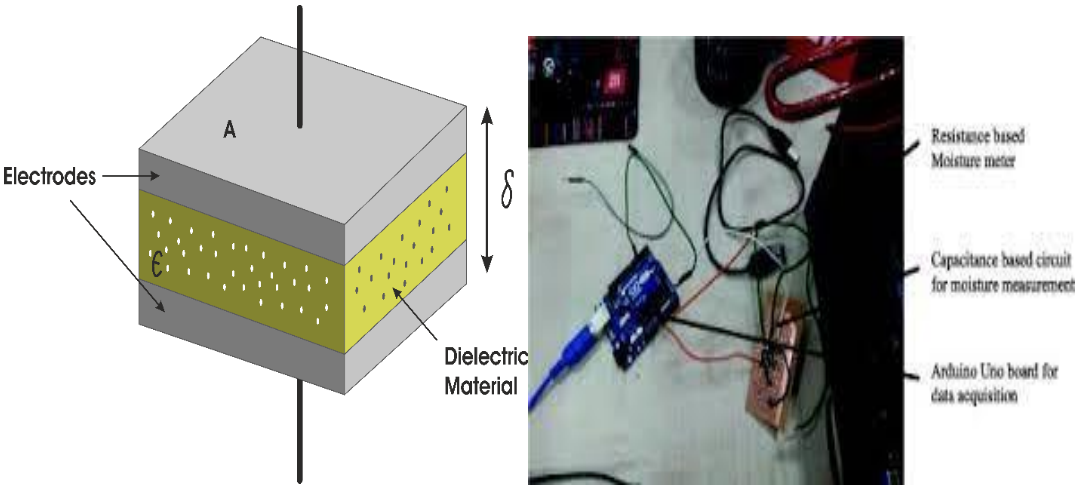


Fig. 1.13: Capacitance-based moisture measurement

1.6 Soil Moisture Stress and Deficit Irrigation

Soil moisture stress

Soil moisture stress takes place when the water present in the plant's cells is reduced to less than its normal level. This can occur because of a lack of water in the plant's root zone, higher rates of transpiration than the rate of moisture uptake by the roots, for example, because of an inability to absorb water due to high salt content in the soil water or loss of roots due to transplantation. Moisture stress is more strongly related to water potential than it is to water content. Too much soil moisture stress may cause loss of yield and poor growth of the plant.

Deficit irrigation

Deficit (or regulated deficit) irrigation is one way of maximizing water use efficiency or in other words, higher yield per unit of irrigation water applied: the crop may be subjected to a certain level of water stress either during a particular period or throughout the whole growing season. The expectation is that any yield reduction would be insignificant compared to the benefits gained through diverting the saved water to irrigate other crops.

ACTIVITIES

Activity 01: Prepare a list of moisture measurement instruments available in the market.

Material required

1. Notebook
2. Pen

Procedure

1. Survey the local market.
2. Visit the instrument shop.
3. Identify the moisture measurement instruments available in the shop.
4. Prepare a list of moisture measurement instruments.
5. Note the specification and working operations.

Activity 02: Draw the line diagram of the tensiometer probe.

Material required

1. Notebook
2. Pencil
3. Eraser

Procedure

1. Identify the tensiometer.
2. Draw the figure of tensiometer.
3. Label the parts of instrument.

Activity 03: **Draw the line diagram of neutron probe** (Neutron moisture meter)**.**

Material required

1. Notebook
2. Pencil
3. Eraser

Procedure

1. Identify the neutron probe (Neutron moisture meter).
2. Draw the figure of the neutron probe.
3. Label the parts of the instrument.

CHECK YOUR PROGRESS

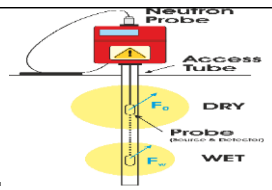
A. Answer the following questions

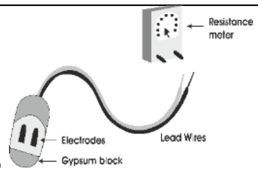
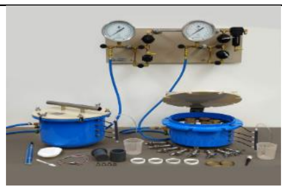
1. Why irrigation scheduling is required?
2. Briefly define net and gross irrigation requirements.
3. Explain irrigation frequency and irrigation period?
4. What do you mean by soil moisture and briefly describe their measurement techniques?
5. Draw the line diagram of the pressure plate apparatus.

B. Fill in the blank

1. A time domain reflectometry (TDR) sensor is used to determine …………………….. in the soil, as well as porous media, both in the laboratory and agricultural land.
2. The pressure is applied from a compressor and maintained at the ……………. level.
3. Neutron probes (Neutron moisture meter) contain …………………. material consisting of the source of fast-moving neutrons.
4. The blocks are buried in the soil at the desired depth and the ……………. is measured with a modified Wheatstone bridge.
5. Irrigation frequency refers to the number of days between two ……………. irrigations during periods without rainfall.
6. 'Irrigation scheduling' is the decision of …………… and ……….. much water to apply in the field crop.

C. Match the following

Column A	Column B
1. Pressure plate apparatus	A. 

2. Gypsum block	B. 
3. Neutron moisture meter	C. 
4. Tensiometer	D. 

Module 2	Design of Sprinkler and Drip Irrigation System

Module Overview

This module covers the fundamentals of irrigation management, including basic concepts, scheduling, and calculating irrigation requirements. Learners will explore soil moisture measurement techniques, the effects of moisture stress, and deficit irrigation strategies to optimize water use, equipping them with the knowledge needed for sustainable agricultural water management.

Learning Outcomes

After completing this module, you will be able to:

- Understand the basic principles and significance of irrigation scheduling.
- Calculate net and gross irrigation requirements for crops.
- Analyze the importance of irrigation frequency and irrigation period in effective water management.
- Identify and apply various soil moisture measurement techniques.
- Evaluate the effects of soil moisture stress on crop growth.
- Implement deficit irrigation strategies to conserve water while maintaining crop productivity.

Module Structure

2.1 Introduction
2.2 Inventory resource of sprinkler irrigation system
2.3 Types of Sprinkler systems and layout
2.4 Capacity of sprinkler systems
2.5 Relationship between sprinkler discharge, diameter of coverage and rate of application
2.6 Drip Irrigation System

2.1 Introduction

Micro irrigation is a low-pressure, low-flow-rate type of irrigation that can reduce the likelihood of overwatering a landscape. This form of irrigation delivers water directly to where it is needed most, i.e. the root zone of the plants. It also delivers the water slowly and over a longer period of time, preventing runoff and reducing evaporation. Micro irrigation systems use 20 to 50 percent less water than conventional irrigation systems and can reduce residential or commercial landscape irrigation water use.

Sprinkler/spray irrigation is the method of applying water to a controlled manner in that is similar to rainfall. The water is distributed through a network that may consist of pumps, valves, pipes, and sprinklers. Irrigation sprinklers can be used for residential, industrial, and agricultural usage.

Drip irrigation or trickle irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface.

Micro irrigation systems must aim at maximising the returns and minimising the cost per unit volume of water used, thus, contributing to the overall reduction in the total investment. Planning and purchasing the correct components are the key factors for the installation and smooth functioning of a micro irrigation system. A checklist of tools, equipment, and material required to install the system must be prepared before purchasing them.

Sprinkler Irrigation System: To achieve high efficiency, a sprinkler irrigation system must be installed and designed properly to suit the conditions of a specific site. The selection of a sprinkler system is based on: I land topography that cannot be properly levelled because doing so would expose the subsoil and the cost of doing so ii) soil texture, specifically the soil's infiltration rate, which ensures that the system's application or precipitation rate is lower than the soil's infiltration rate. The sprinkler system's capacity must eventually match the crops' water needs, and it must also have a high water application efficiency. Finally, it must be economically feasible from the perspective of crop production. Therefore, some invent resources are elaborate on below;

2.2 Inventory resource of sprinkler irrigation system

The inventory of resources includes the following:

i) **Water Resources:** It is a very important inventory resource for sprinkler irrigation systems. In the design of a sprinkler system, the basic requirement is water resources and information on how much quantity and quality of water is available. The quantity of the water resources in terms of the seasonal availability of the water; discharge available for irrigating the field and the duration for which it is available per day are required to match with the crop water requirement. This information is particularly required for deciding whether the entire area of the proposed field or a portion of the area of the field can be irrigated. The location of the source of water in the field is desired to estimate the length and diameter of the main, sub-main, and lateral pipes. The water quality parameters include EC, pH, and SAR. Some crops may have a detrimental or scorching effect on leaves, if water has high soluble salts used for sprinkling water. The quality of water is, thus, important to decide its suitability for crops for sprinkler irrigation. This information is also required for deciding the irrigation frequency. Water with high soluble salt contents may be required to be applied more frequently compared to good quality water.

ii) **Topography map of the area:** The topography map of the field needs to be prepared. The map should include the field boundaries and the locations of the bunds, farm road, buildings, and location of water resources. The map may also include possibly the areas selected for the cultivation of different crops in the field. This is required for knowing the total area to be irrigated for different crops and then estimating the quantity of water required for each irrigation. The map should also include the contour map of the area. The contour map enables us to determine the slope of the field, if any, in both directions. The slope is required to decide the layout and placement of the pipe network (main, sub-main, and laterals) and computation of the elevation difference which is required for the design of pipes in terms of their diameter and length.

iii) **Soils:** It is another important inventory resource for a sprinkler irrigation system. The soil parameters such as field capacity, wilting point, bulk density, and infiltration rate are used for irrigation system design. Field capacity, wilting point, and bulk density is required for estimating the available soil water in the root zone. Allowable soil water depletion for a specified crop and climate data are required for computing the depth of irrigation and frequency of irrigation. The information on infiltration rate is used in selecting the nozzle size, type of nozzle, and lateral spacing.

iv) **Climate:** The weather parameters such as pan evaporation, rainfall, temperature, relative humidity, wind speed, and sunshine hours are required to compute the water requirement of the crops. The peak water requirement estimation requires peak summer weather parameters such as solar radiation, temperature, humidity, etc.

v) **Crops to be Irrigated:** The information on crops, their root zone depth, crop coefficient, and allowable depletion level is required for computing the water requirement of the crops and irrigation frequency. The climatic and soil parameters are required to determine crop water requirements.

vi) **Availability of Power Source:** The type of source of power can be electricity or diesel or both. The irrigation system can be planned and designed based on the assured timings of the availability of power supply.

2.3 Types of Sprinkler systems and layout

The layout of a sprinkler system is made based on the water source and the location of the water supply. The source of water supply for sprinkler irrigation can be surface water (river, canal, pond, etc.) or groundwater (a tube well or open well). When deciding the location of the well, it can be located at a corner or, at the center of the farm to minimize the length of the main pipe. The source at a higher elevation is desirable. The layout of the mains depends on the location of the well. Fig. 2.1 shows the layout of the stationary water source and pump at the center of the field and laterals are moved to successive positions up one side of the main and then down on the other. Fig. 2.2 shows a fully portable pumping set unit. In a Portable sprinkler system field channel runs along one edge of the farm. In this system, a portable pumping set and sprinkler unit with a lateral extending to the field are used to draw water directly from the channel and distribute it through the sprinklers. Another alternative is to have a permanent pumping plant at the source and distribute water in buried pressurized pipelines. These pipelines will usually run down the center of the field so that the outlets offer little hindrance to tillage and other farm operations.

To obtain a reasonable degree of uniformity in the discharge of each sprinkler, the mains should run in the direction of the steepest slope, with the laterals at right angles and as close as on contours. Generally, design is made considering running on a level and if the lateral slopes upgrade appreciably, it is difficult to design for a very long pipe length. If it slopes downgrade, the length can be longer than usual, but rarely does the slope remains uniform for each setting.

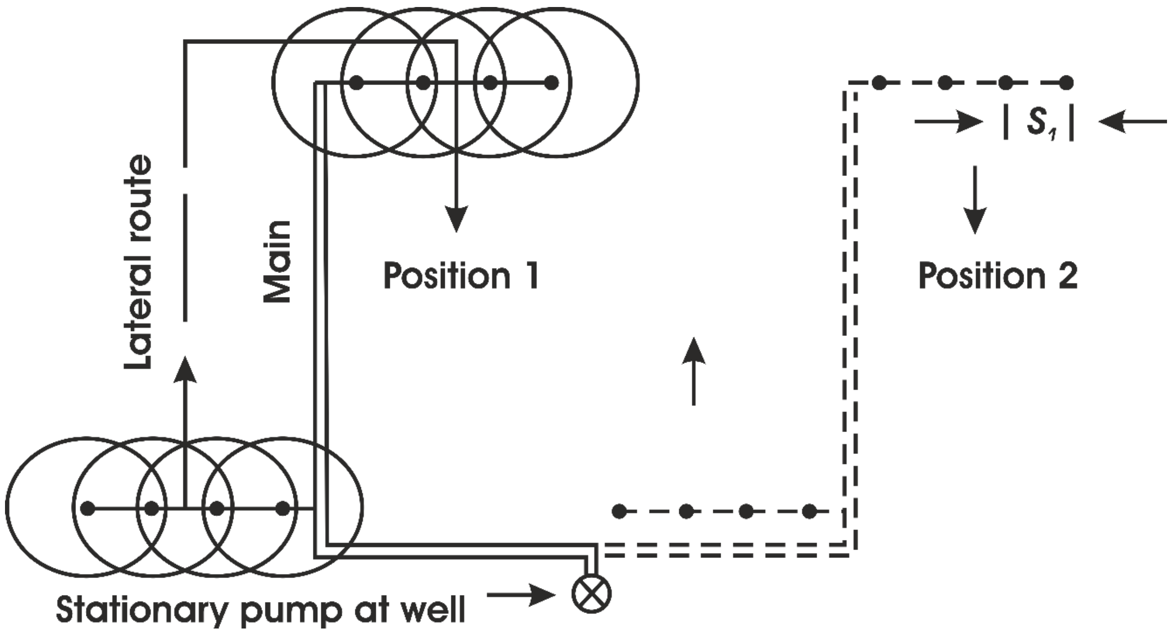


Fig. 2.1: Layout plan for sprinkler irrigation system for stationary water Source of well and pump. (Source: Michael, 2010)

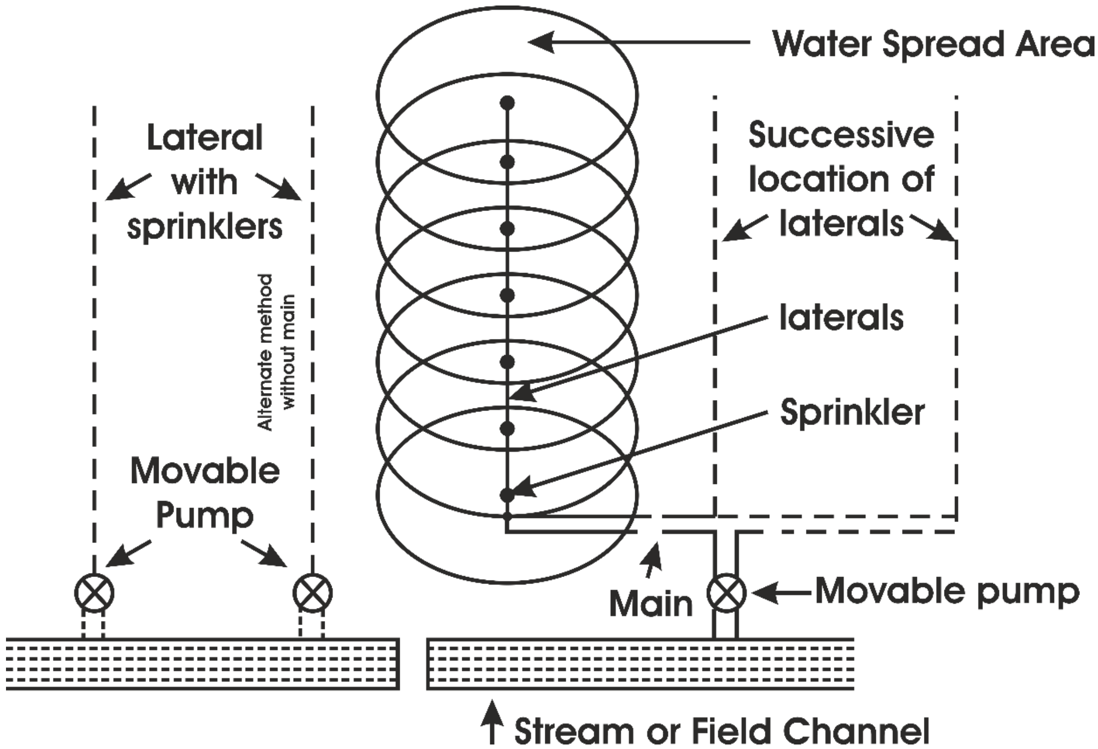


Fig. 2.2: Typical field layouts for fully portable sprinkler units drawing water from streams or field channels. (Source: Michael, 2010)

(I) Layout for Set-Move Sprinkler System

Different layouts for set-move sprinkle systems are shown in Figs. 2.3 (a), (b), (c), (d), (e), & (f). The guidelines for set-move sprinkler system are stated below:

a) The main pipeline should be laid up and downhill.
b) Laterals should be laid across slope or nearly on the contour.
c) For multiple lateral option, lateral pipe sizes should be limited to not more than two diameters.
d) If possible, water supply nearest to the center of area should be chosen.
e) Layouts should facilitate minimal lateral movement during a crop season.
f) Differences in number of sprinklers operating for various setups should be minimum.
g) Booster pumps should be considered where small portions of field would require high pressure at the pump.
h) Layout should be modified to apply different rates and amounts of water where soils are greatly different in the design area.
i) Mainline and sub-main layout are keyed to the lateral layout.
j) When laterals run across prominent slopes, mainlines or sub mains will normally run up and down the slopes Fig 2.3(a) and (b).

k) When it is necessary to run laterals up and downhill, the mainlines or sub mains should be located on ridges Fig 2.3(c), (d), (e) & (f) to avoid laterals to run uphill.

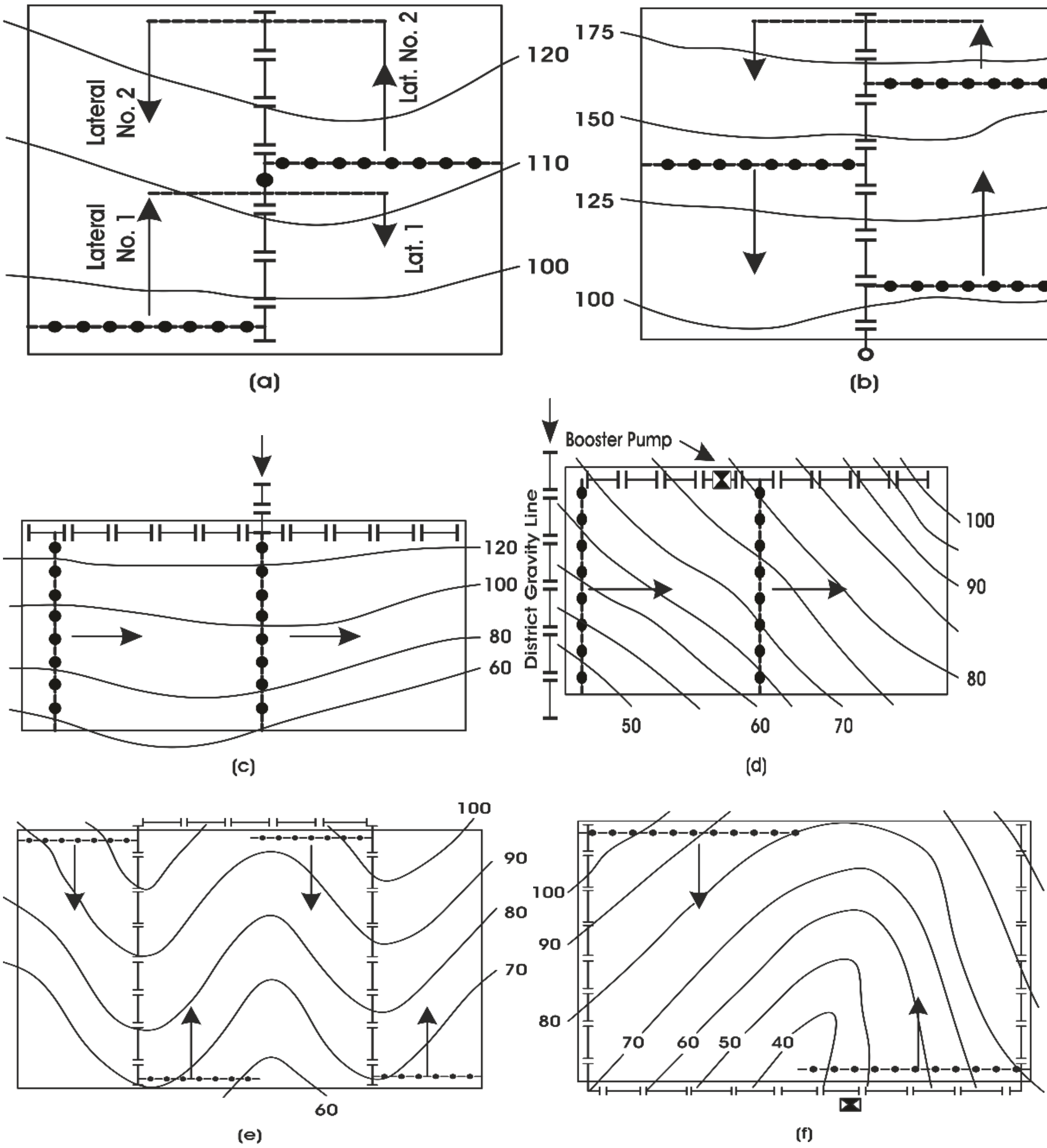


Fig. 2.3: Layouts for set-move sprinkle systems (a),(b),(c),(d),(e) and (f). (Source: James Larry, 1988)

Fig. 2.3 (a) Layout on moderate, uniform slopes with water supply at center (b) Layout illustrating use of odd number of laterals to provide required number of operating sprinklers. (c) Layout with gravity pressure where pressure gain approximates friction loss and allows running laterals downhill. (d) Layout illustrating area where laterals have to be laid downslope to avoid wide pressure variation caused by running laterals upslope. (e) Layout with two main lines on ridges to avoid running laterals uphill. (f) Layout with two main lines on the sides of the area to avoid running the laterals uphill.

(II) Split Lateral Layouts

a) In this layout mainlines and sub mains are located such that set move laterals may operate on either side of them (Fig. 2.3 (a), (b) and (e)).
b) They minimize friction loss because of shorter laterals.
c) Split layouts also allow set-move laterals to be rotated around mainlines (Fig.2.3 (a), (b)).
d) Labor requirement is reduced by eliminating the need to move lateral pipes back to starting point (Fig 2.3(c) and 2.3(d)).

2.3 Sprinkler selection and spacing parameters

a) **Sprinkler discharge considering area of coverage:** The actual selection of different components of the sprinkler system is based on specifications furnished by the manufacturers of the equipment. The selection depends on the wetting diameter of the nozzle, at a given operating pressure at the nozzle, sprinkler discharge, a combination of sprinkler spacing and lateral moves, and application rate suiting soil and wind conditions. The required discharge of an individual sprinkler is a function of the water application rate and the two-way spacing of the sprinklers. It may be determined by the following equation:

$$\mathbf{q = \frac{Sl \ x \ Sm \ x \ I}{3600}}$$

Where,

q = required discharge of individual sprinkler, l/s
S1 = spacing of sprinklers along the lateral, m
Sm = spacing of laterals along the main, m
I = optimum application rate, cm/h or mm

b) **Height of Sprinkler Riser Pipes:** Sprinklers are located just above the crops to be irrigated and, therefore, the height of the risers depends upon the maximum height of the crop. To avoid excessive turbulence in the riser pipes, the minimum height of the riser is 300 mm for 25 mm diameter and 150 mm for 15 mm to 20 mm diameter.

c) **Sprinkler Spacing:** The uniformity of water distribution from sprinklers depends on the operating pressure, wind velocity, rotation of sprinklers, and spacing between sprinklers and laterals. The spacing of sprinklers on laterals and the laterals spacing is adjusted for obtaining maximum uniformity for a given condition. Greater depth of water accumulate near the sprinkler head and depth decreases gradually with distance from the sprinklers. Therefore, there is a necessity of overlapping the spray pattern of the individual sprinkler, to obtain a uniform depth of water application.

d) **Capacity of a sprinkler system:** The capacity of a sprinkler system is an important design parameter. This is estimated after knowing the total area to be irrigated by a sprinkler irrigation system. The formula to compute system capacity is given by:

$$Q = 2780 \frac{A \text{ x } d}{F \text{ x } H \text{ x } E}$$

Where,
Q = discharge capacity of the pump, l/s
A = area to be irrigated, ha
d = net depth of water application, cm
F = number of days allowed for the completion of one irrigation
H = number of actual operating hours per day
E = water application efficiency, percent

e) **Sprinkler Discharge:** The discharge of a sprinkler is estimated by knowing the diameter of the nozzle and operating pressure available at the nozzle by following the formula.

$$Q = CA\sqrt{2gh}$$

Where,
Q = discharge, cm^3/s
C = sprinkler discharge coefficient which vary from 0.80 to 0.95
A = cross–sectional area of nozzle or orifice, cm^2
g = acceleration due to gravity, cm/s^2, and
h = pressure head, cm

f) **Spread of Sprinkler:** The area covered by a rotating head sprinkler can be estimated from the formula stated in equation given below:

$$R = 1.35\sqrt{dh}$$

Where,
R = radius of the wetted area covered by sprinkler, m
d = diameter of nozzle, m
h = pressure head at nozzle, m

The maximum coverage is attained when the jet emerges from the sprinkler nozzle at angle between 30^0 and 32^0.

g) **Rate of Water Application or Precipitation Intensity:** The rate of water application by an individual nozzle is estimated by the formula as stated below.

$$\mathbf{Ra} = \frac{\mathbf{Q}}{\mathbf{360\ x\ A}}$$

Where,
Ra = rate of water application, cm/h
Q = rate of discharge of sprinkler, l/s
A = wetted of sprinkler, m^2

2.4 Capacity of sprinkler systems

Capacity of the pump to be used depends on the area to be irrigated, application depth at each irrigation, irrigation frequency, pump operating hours per day and irrigation efficiency. Capacity is given by:

$$\mathbf{Q} = \mathbf{2780}\frac{\mathbf{A\ x\ d}}{\mathbf{F\ x\ H\ x\ E}}$$

Where,

Q = capacity of the pump (lps)
A = area to be irrigated (ha)
d = depth of application (cm)
F = number of days allowed for completing one irrigation
H = operation hours / day
E = irrigation efficiency (%)

2.5 Relationship between sprinkler discharge, diameter of coverage and rate of application

The values of a maximum rate of application for various soil types and slopes are presented in Table 2.1.

Table: 2.1 Maximum application rates for different types of soils

Soil texture and profile	0 to 5% slope	5 to 8 % slope	8 to 12 % slope
Coarse sandy soils to 2 m	5.10	3.75	2.54
Coarse sandy soils over more compact soils	3.75	2.54	1.90
Light sandy loams to 2 m	2.54	2.03	1.50
Light sandy loams over more compact soil	1.90	1.27	1.02
Silt loam to 2 m	1.27	1.02	0.76
Silt loams over more compact soils	0.76	0.63	0.38
Heavy textured clays or clay loams	0.38	0.25	0.20

Sprinklers are arranged along a lateral such that the diameter of the water spread area of sprinkler is overlapped. If there is a wind of considerable speed, the spacing between sprinklers is further reduced as given in Table 2.2.

Table. 2.2. Overlapping of sprinkler spacing for different wind speeds

S.No.	Average wind speed	Spacing
1.	No wind	65% of the water spread area of a sprinkler
2.	0-6 km/h	60% of the water spread area of a sprinkler
3.	6.5- 13 km/h	50% of the water spread area of a sprinkler
4.	Above 13 km/h	30% of the water spread area of a sprinkler

Source: Soil Conservation Service (1993)

2.6 Drip Irrigation System: The estimation of the water requirements of the crops to be watered, the number of drippers and laterals, the diameter of the main, sub-main, and lateral pipes, and the size of the pumping unit are all factors in the design of a drip irrigation system. The information that must be gathered includes information on the type of soil, infiltration, soil characteristics, type of crop, and the availability of funds. Planning and setting up the system requires a topographical map of the area to be irrigated with contour lines spaced at about one metre intervals. The following is a list of steps for designing a drip irrigation system;

2.6.1 Planning and Design of Drip Irrigation System

The planning and the design of a drip irrigation system are essential to supply the required quantity of irrigation water to the crop at a desired uniformity. The main purpose of the design of a drip irrigation system is to decide the dimensions of various components of the system such that the system provides the required quantity of water at the desired uniformity in the application while keeping the cost of the system to a minimum. To apply the desired amount of water at a nearly uniform rate to all the plants in the field, it is essential to design the irrigation system that maintains the desired hydraulic pressure in the pipe network and provides the desired operating pressure at the emitter. The design of the drip irrigation system consists of a selection of emission devices, the size of laterals, manifolds, sub-main, main pipeline, filter, and pump. The system design depends on many factors, but the design will be constrained by several economic factors such as feasibility, initial investment, labour, return on investment, and performance parameters such as the rated flow rate and desired emission uniformity. The steps to be followed for designing the drip irrigation system are given below:

1. Inventory of the resources and data collection.
2. Computation of peak crop water requirement.
3. Deciding the appropriate layout of the drip irrigation system.
4. Selection of emitters.

5. Hydraulic design of the system in terms of lateral, sub main and main.
6. Horse power requirement of pump.

2.6.2 Inventory Resources and Data Collection

This step involves the preparation of inventory of all the available resources and operating conditions. The resources involved include:

1. **Water resources:** Quantity (stream size, volume and duration for which the supply is available) and quality of water, the type of water resources i.e. bore/tube well; open dug well, reservoir/pond/tank or river, and location of the water resource.
2. **Land resources:** The size and shape of the area to be irrigated, soil type for its texture, and irrigation properties (field capacity, wilting point, bulk density, allowable depletion level) including infiltration rate, and topography of the land.
3. **Climate:** The climatic data required for the computation of crop water requirements.
4. **Crop:** Crop type, sowing/planting and harvesting period, crop coefficient, fertiliser requirements, crop geometry. In general, following guidelines can be used to ensure an adequate quantity of available water for the supply of irrigation water to the wide-spaced (orchard) and close-spaced (vegetable etc.) crops. However, the area to be irrigated can be decided on the basis of the water availability and the crop water demand.

Essential parameters	Orchard Crops	Vegetables and other closely spaced crops
Stream Size	$1Ls^{-1}/ha^{-1}$ for 4 h day^{-1}	$3Lp^{-1}$ ha^{-1} for 4 h day^{-1}
Storage capacity	$15m^3ha^{-1}$	$45m^3ha^{-1}$
Power requirement	1hp ha^{-1}	3hp ha^{-1}

2.6.3 Peak Crop Water Requirement

The design of the drip irrigation system needs information on the peak water requirement, however, while the system is in operation, the water requirement during the specified irrigation interval is required. This section describes the method to estimate the crop water requirement. The water requirement of crops is a function of plants, the surface area covered by plants, and the evapotranspiration rate. The crop water requirement is calculated for each plant and the water requirement of the whole area is estimated based on the water requirement per plant and the total number of plants. The crop water requirement which is maximum during any one of the three seasons is adopted for system design.

The daily water requirement for fully grown plants can be calculated as under:

$$V = ETr \times Kc \times A \times Wp$$

Net volume of water to be applied

$$Vn = V - \mathrm{Re} \times A \times Wp$$

Number of daily operating hours of the system

$$(T) = \frac{V_n}{Ne \times Np \times q}$$

Where,

V = Volume of water required, L

ET_r = Reference crop evapotranspiration, mm day^{-1}

Kc = Crop coefficient

A = Area occupied by a plant (row-to-row spacing x plant-to-plant spacing), m^2

R_e = Effective rainfall, mm

W_p = Wetting fraction (varies from 0.2 for wide-spaced crops and 1.0 for close-spaced crops)

Ne = Number of emitters per plant

N_p = Number of plants

q = Emitter discharge, L h^{-1}

The crop coefficient (Kc) varies with crop growth stage and season. The crop coefficient (Kc) should be considered for the maturity stage of the crop while designing the micro irrigation system and for the specified growth while operating the system.

The water requirement of a few crops is given in Table 2.3, which can be used as a guideline for the design of drip irrigation system. However, it should be noted that this is only a guideline and actual water requirement needs to be computed on the basis of crop, climate, etc.

Table no.2.3: Water requirements of a few horticultural crops

Name of Crop	Spacing (m)	Water Requirement (l/plant/day)	
		Minimum	Maximum
Banana	2.0 x 2.0	4	18
Papaya	2.0 x 2.0	2	10
Guava	5.0 x 5.0	14	39
Mango	5.0 x 5.0	20	50
Pineapple	0.45 x 0.25	0.1	0.6
Cashew	7.5 x 7.5	25	60
Jujube	6.0 x 6.0	20	50
Sapheda	5.0 x 5.0	20	65
Pomegranate	5.0 x 5.0	15	40
Tomato	0.6 x 0.6	0.45	1.15
Cauliflower	0.6 x 0.45	0.7	1.4
Okra	0.3 x 0.3	0.6	1.8

2.6.4 Layout of the Drip Irrigation System

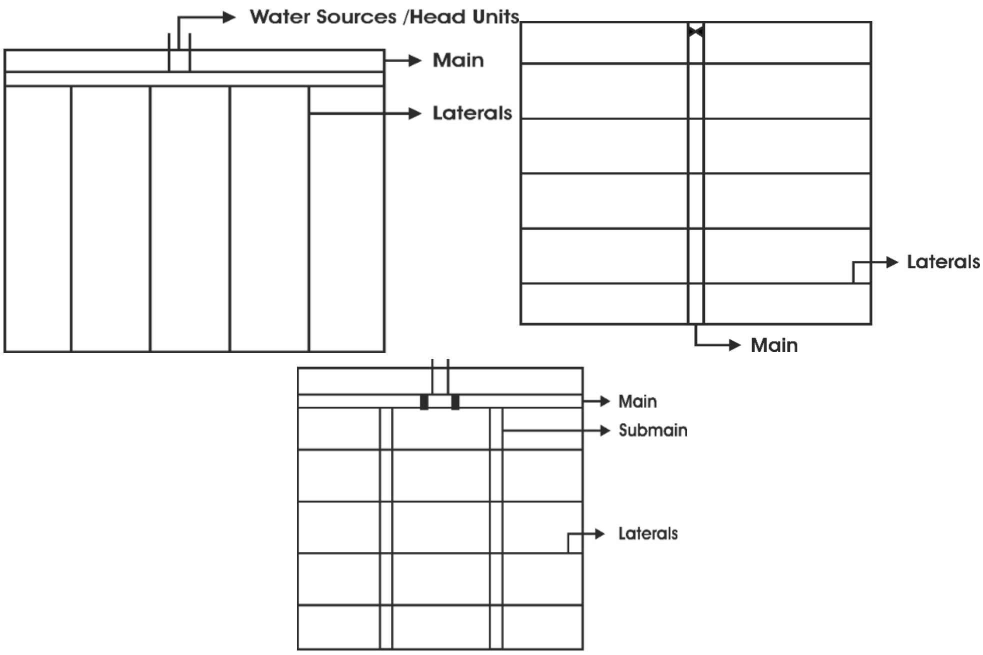
It is possible to apply water to the whole field by drip irrigation method at the same time. However, this may result in the requirement of high discharge which may not be available, the further large diameter of mains and sub main which could make the system more expensive, and the high capacities of the fertigation and filtration units. Hence the whole field needs to be divided into a convenient number of subunits. Each subunit is then designed separately and operated separately by having a valve at the head of the subunit. The number of subunits is calculated as:

$$\textbf{Number of subunits} = \frac{\text{Total time available for irrigation}}{\text{(time of operation for drip) system}}$$

The total time available for irrigation depends on the hours of electricity available in the region, and the capacity of the farmers to supplement the electricity by other means such as diesel engines/generators, etc.

The system requirement or discharge for the individual subunit is then computed. If it is more than the available discharge from the water resources, the area under each subunit is then proportionally reduced to match the discharge requirement with the available discharge.

The layout of the micro irrigation system, i.e. the arrangement of the main, sub mains, and laterals is done considering the shape, size, and slope of the field. As far as possible, the sub-main should run along the slope of the field and the lateral should be laid across the slope or along the contour lines of the field. Different layouts design of the drip irrigation system is shown in Fig. 2.4.



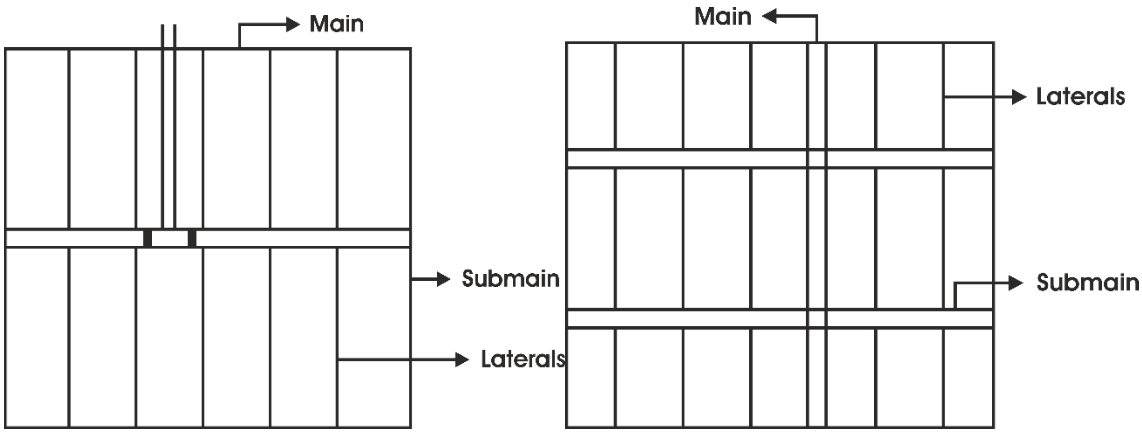


Fig. 2.4: Layout design of Drip Irrigation System

Once the layout is finalized, the diameter and the l;ength of the submain and laterals for each subunit are decide on the basis of hydraulic design of the pipe. Which is explained in subsequent sections. The spacing between lateral depends on the crop geometry for the row crops. For the plantation or orchard crops, the spacing between laterals is equal to the row spacing. However, depending on the age of a tree, tree spacing and soil type,two laterals per row of the tree may be needed. The spacing between the emitters on laterals for row crops is governed by the soil type whereas, in the case of plantation or tree crops, the number of emitters per tree is governed by the spacing, age, and soil type.

2.6.5 Selection of Emitters

The emitters are to be selected for their discharge, operating pressure, online/inline, pressure compensating/non-pressure compensating, point source/line source, single exit/multi exit, and surface/subsurface. The selection of a particular type of emitter depends on the soil, crop, topography, desired emission uniformity, available discharge, electricity/other sources for the operation of the system, water quality, water use efficiency, and cost.

Soil: The discharge of the emitters should be less than the infiltration rate of the soil. Soil type also governs the spacing between emitters. Heavier the soils, more could be the more spacing.

Crop: In case of row crops, emitters need to be spaced so as to wet the entire strip of the row. In case of close growing and row crops, inline/integrated emitters are preferred, whereas for the plantation/orchards, online emitters are preferable. Single-exit emitters are used for row crops while multi-exit emitters are suitable for plantation crops.

Topography: Non-pressure compensating emitters could be used for relatively flat lands whereas on land with rolling or uneven topography, pressure compensating emitters are preferable.

Emission Uniformity: Pressure-compensating emitters are capable of providing more uniformity compared to non-pressure-compensating emitters.

Discharge Available: When the discharge available is small, the emitters with low discharge need to be used. However, these emitters may need more time to operate.

Water Use Efficiency: Subsurface drip irrigation reduces the evaporation losses compared to surface drip; thus, resulting in more water use efficiency.

Water Quality: The emitters with more diameter or cross-sectional area need to be used for water with a heavy load of suspended solids.

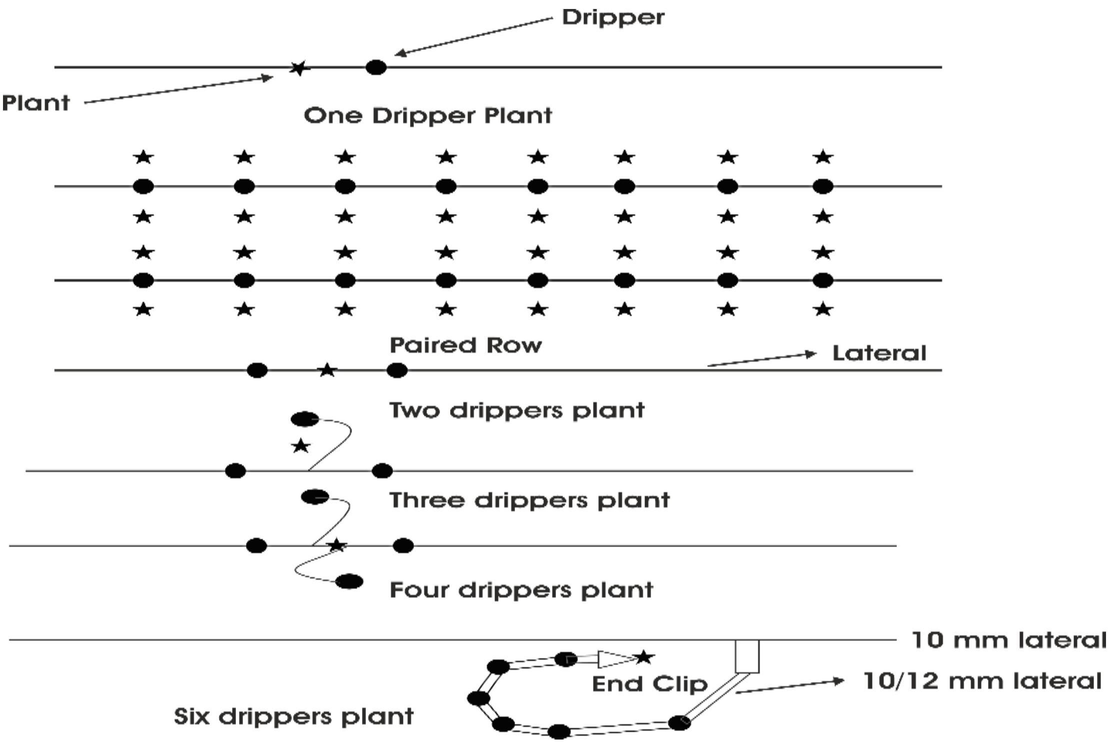


Fig. 2.5: Different arrangement of emitters along the laterals

2.6.6 Hydraulic Design of Pipe Network

The pipe network in the drip irrigation system consists of laterals, sub-main and main. Water under pressure flows through these pipes and as a result, the pressure in the pipes reduces creating the variation in pressure or pressure difference between any two points. The emitter discharge depends on the operating pressure available in the pipe at the emitter connection and reduces with reducing pressure. Therefore, there is variation in discharge obtained by the emitters in the system; affecting the emission uniformity.

Ideally, the emitters should give the same discharge at different operating pressure. However, only pressure-compensating emitters are capable of giving the same discharge over a certain range of pressure variation. But these emitters are expensive. The alternative is to design the system with non-pressure compensating emitters such that the same discharge is available at all the points. From the practical point of view, it is almost impossible to achieve this ideal performance. However, the flow variation of water pressure can be minimized by the appropriate hydraulic design.

As per the principle of hydraulics, the minimum pressure variation along the laterals/sub-main can be obtained by keeping the diameter of the pipes as large as possible and the length as minimum as possible. But doing this is expensive. On the other hand, decreasing the diameter and increasing the length, though less expensive, reduces the performance of the system in terms of emission uniformity. In order to have a trade-off between the economy and efficiency, the criterion of allowing the variation in the discharge of 10% amongst any two emitters in the subunit is adopted. This is equivalent to a 20% variation in pressure for the turbulent type of emitters and a 10-15% variation for long-path emitters. Of the total allowable head loss in the subunit, 55% head loss is allowed in laterals and the remaining 45% in the sub-main.

The procedure of hydraulic design consists of:

1. Know the operating pressure of emitters.
2. Find out the allowable head loss in lateral and sub main.
3. Find out the lateral and sub-main discharge.
4. Find out the diameter and length of the lateral such that the head loss in the lateral is within allowable limits for the given layout. For this purpose, find out the head loss by Hazen William or Darcy-Weisbach formula for different combinations of diameter and length and select the suitable combination by trial and error method.
5. Repeat the procedure for the sub main.
6. Find out the diameter of the main so that the velocity is within the allowable limit or find out the head loss in the main for the specified diameter of the main. The length of the main is the distance of the field from the water source.

2.6.6.1 Computation of Discharge of Lateral, Sub Main, and Main

Flow carried by each lateral line

Q_1 = Discharge of one emitter x No. of emitters per lateral

Flow carried by each sub-main line Q = Q_1 x No. of lateral lines per sub main

Flow carried by the main Q = Q_1 x No. of sub-main line

The diameter of the main, sub-main, and laterals are chosen based on the hydraulics of pipe flow. The pressure drop due to friction can be evaluated with the help of Hazen William or Darcy-Weisbach equation as stated above.

i) Head Loss in Laterals

The pipes used in micro irrigation systems are made of plastics (PVC, HDPE, LDPE, or LLDPE) and are considered smooth pipes. The pressure drop due to friction or frictional head loss can be evaluated with the help of the Hazen -William empirical equation as follows.

$$H_f(100) = K\left(\frac{Q}{C}\right)^{1.852} \times D^{-4.871} \times F$$

As the length of the pipe increases, the discharge in the pipe decreases due to emission outlets, and hence the total energy drop is less than as estimated by the above equation. For this reason, a reduction factor F which is less than 1.0 is introduced in the equation. Head loss for the specified length of pipe is

Hfl = Hf x (L+Le|)/100

Where,

H_f (100) = head loss due to friction per 100 meter of pipe length, m/100m
Hfl = head loss in the specified length of lateral
Q = Flow of water in pipe, Ls^{-1}
D = Internal diameter of pipe, cm
L = Length of the pipe, m
C = Hazen-William constant (140 for PVC pipe)
K = 1.22×10^{12}
Le = equivalent length of the pipe

= Ne*fe

Ne = number of emitters on a lateral
fe = equivalent length due to one emitter connection
fe = 1 to 3 m for in-line emitter with barbed connection
fe = 0.1 to 0.6 for online emitters
F = Reduction factor due to multiple openings in the pipe, which can be computed by the following equation.

$$F = \frac{1}{m+1} + \frac{1}{2N} + \frac{\sqrt{m-1}}{6N^2}$$

$$m = 1.852$$

N = Number of outlets on the lateral

As stated before, the design criteria for lateral pipe is to keep pressure and discharge variations within the prescribed limit.

ii) Head Loss in Sub mains

The sub-main line hydraulics of sub mains pipe is similar to that of the lateral hydraulics. The sub-main hydraulics characteristics can be computed by assuming the laterals are analogous to emitters on a lateral line, except for the fact that is considered zero in this case due to the relatively smooth connection of laterals to submain. Hydraulic characteristics of sub main and mainline pipe for the drip system are usually taken hydraulically smooth pipe due to PVC and HDPE pipe material. The Hazen-Williams roughness coefficient (C) varies between 140 and 150. The energy loss in the sub-main is computed in the same way as used for lateral.

iii) Head Loss in Main Line

Usually, pressure controls or adjustments are provided at the sub-main inlet. Therefore, energy loss in the mainline should not affect the system's uniformity. In the case of the main line, the value of the reduction factor (F) is the unity (1). The frictional head loss in the main pipeline is calculated by the same equation Darcy-Weisbach formula or Hazen-Williams.

2.6.7: Horsepower Requirement of Pump

The horsepower requirement of the pump is computed by the following equation.

$$\textbf{Horsepower required (hp)} = \frac{H \times Q_m}{75 \times \eta_p \times \eta_m}$$

Where,

H = total pumping head ($H_f + H_e + H_S$), m
H_f = Total head loss due to friction (Friction head loss in mains + Friction head loss in sub mains + Friction loss in laterals + Head loss in accessories, filters, and fertigation unit), m
H_e = Operating pressure head required at the emitter, m
H_S = Total static head, m
Q_m = Discharge of main
h_p = Efficiency of pump
h_m = Efficiency of motor

ACTIVITIES

Activity 01: Prepare a list of inventory resources of the sprinkler irrigation system.

Material required

1. Notebook
2. Pen

Procedure

1. Visit the agriculture field.
2. Identify the inventory resources of the sprinkler irrigation system.
3. Make a list of inventory resources which is required for the sprinkler irrigation system.

Activity 02: Design the layout of the drip irrigation system.

Material required

1. Notebook
2. Pencil
3. Eraser

Procedure

1. Visit the agriculture field.
2. Identify the area where will be drip irrigation system installed.
3. List resources required for the drip irrigation design.
4. Design the layout of the drip irrigation system.

CHECK YOUR PROGRESS

A. Answer the following questions

1. Explain inventory resources used in sprinkler and drip irrigation systems.
2. Write the selection criteria for the sprinkler system.
3. Describe the design parameters of the sprinkler irrigation system.
4. What do you mean by peak water requirement.
5. Write down the water requirements of a few horticultural crops.
6. Calculate the computation of discharge of lateral, sub-main, and main lines.
7. Describe the design parameters of the drip irrigation system.

B. Fill in the blank

1. The ………. and ………. of a drip irrigation system are essential to supply the required quantity of irrigation water to the crop at a desired uniformity.
2. The ……….. map enables us to determine the slope of the field, if any, in both directions.
3. The layout of a sprinkler system is made based on the ………… and the location of the water supply.
4. The crop coefficient (Kc) varies with crop growth ……… and …………….

5. Ideally, the emitters should give the same ……………… at different operating pressure.
6. The climatic data required for the …………….. of crop water requirements.
7. Greater depth of water accumulate near the sprinkler head and depth …………….. gradually with distance from the sprinklers.
8. To avoid excessive …………….. in the riser pipes the minimum height of the riser is 300 mm for 25 mm diameter and 150 mm for 15 mm to 20 mm diameter.
9. When the discharge available is small, the emitters with ………... discharge need to be used.
10. The water requirement of crops is a …………. of plants, the surface area covered by plants, and the evapotranspiration rate.
11. The discharge of the emitters should be less than the ………. rate of the soil.

Module 3	FERTIGATION

Module Overview

This module focuses on the fundamental concepts and practices of irrigation management. It introduces learners to key topics such as the basics of irrigation, the importance of scheduling, and the calculation of irrigation requirements. Learners will explore techniques for measuring soil moisture, understand the implications of soil moisture stress, and learn about deficit irrigation strategies to optimize water use. This module equips students with essential knowledge to manage water resources effectively for agricultural sustainability.

Learning Outcomes

After completing this module, you will be able to:

- Understand the basic principles and significance of irrigation scheduling.
- Calculate net and gross irrigation requirements for crops.
- Analyse the importance of irrigation frequency and irrigation period in effective water management.
- Identify and apply various soil moisture measurement techniques.
- Evaluate the effects of soil moisture stress on crop growth.
- Implement deficit irrigation strategies to conserve water while maintaining crop productivity.

Module Structure

3.1 Introduction
3.2 Macro and Micro Nutrients
3.3 Function and deficiency of plant nutrient
3.4 Application of fertilizer
3.5 Method of fertigation
3.6 Fertilizers suitable for fertigation
3.7 Main fertilizers used for fertigation
3.8 Factors for consideration in fertigation
3.9 Advantage of Fertigation
3.10 Limitation of Fertigation
3.11 Common considerations in fertigation
3.12 Precautions
3.13 Stock solution
3.14 Equipment of Fertigation

3.1 Introduction

Fertigation is an advanced technique to apply fertilizer to crops along with irrigation water into the region where most of the plant's roots develop. It permits the application of fertilizer at a slow and controlled rate directly to the root zone; fertigation provides the flexibility of fertilizers which enables specific nutritional requirements of the crop to be made at different stages of the crop growth.

In the present scenario, the use of fertilizer directly in the soil arouses many problems like uneven consumption of fertilizer resulting in variation of crop yield, low nutrient use efficiency of fertilizer, and contamination of soil and water due to excess fertilizer uses. Excessive fertilizer application increases the cost of fertigation and labour requirements. The conventional method of fertilizer application not only limits the crop yield; therefore, we need efficient techniques like fertigation.

3.2 Macro and Micro Nutrients

Nutrients are vital in the overall development of the plant. Continuous use of land causes depletion of nutrients in the soil, therefore, the essential elements should be added from time to time to enrich the soil, so the nutrient requirement of the plant is satisfied. The elements which are required for the growth of the plant is called plant nutrients, plant contains more than 90 elements out of which 17 elements are called micronutrients and macronutrients.

There are two types of plant nutrients

1. Macro Nutrients 2. Micro Nutrients

a) Macronutrients: Nutrients that are required in larger amounts by plants such as Carbon (C), Hydrogen (H), Oxygen(O), Nitrogen (N), Phosphorus(P), Potassium(K), Calcium (Ca), Magnesium (Mg), and Sulfur (S).

b) Micro Nutrients: Nutrients that are required in smaller amounts by plants such as Boron (B), Chlorine (Cl), Copper (Cu), Iron (Fe), Manganese (Mn), Zinc (Zn), Molybdenum (Mo) and Cobalt (Co).

3.3 Function and deficiency of plant nutrient

Table 3.1: Function and deficiency of plant nutrient

Nutrients	Function	Deficiency
Nitrogen (N): Available to plant in the form of nitrate (NO_3^-) and ammonium (NH_4^+) ions.	Nitrogen is an essential constituent of all protein, chlorophyll, and nucleic acid which help in plant growth and provides green color to the plant. It improves the quality of	Reduction of cell division tends to slow and stunted the growth of plat. General chlorosis of the older leaves. Pale green to light yellow color on the leaves.

	dry matter in leafy vegetables and fodder and the protein content of the grain crop.	
Phosphorous (P): Available to plant in the form of (HPO_4^{2-}), ($H_2PO_4^{-}$) ions.	Phosphorous is required by plants for the development of energy, sugars, and starch. It helps in the development of systems, fruit formation, and maturity. Increase resistance of the crop to diseases.	Premature fruit drop. Overall stunted growth of the crop. Poor root development of the crop.
Potassium (K): Available to plants in the form of (K^{+}) ion.	Potassium is an enzyme activator that helps in metabolism. It is necessary for young plants. It regulates the opening and closing stomata of the leaf and controls the ion movement.	Reduce the resistance of crops to diseases. Slender and weak development of the stalk and straw which causes lodging and straw breakage reducing the yield of a crop.
Calcium (Ca): Available to plants in the form of (Ca^{2+}) ion.	Calcium is an essential constituent of the cell wall structure which helps in providing stiffness to the plant. It helps in the stability of the membrane and provides integrity to cell structure.	Calcium is immobile in the plant which causes deficiency in the younger leaves. Young leaves become cup-shaped and crinkled and deterioration of the terminal bud as well as in some cases buds and blossom falls prematurely.
Magnesium (Mg): Available to plant in the form of (Mg^{2+})	Magnesium is primarily a constituent of chlorophyll which is essential in photosynthesis that imparts dark green color in leaves. It helps in the movement of sugar in the plant.	In interveinal chlorosis of the older leaves of the plant, leaf tissue between the veins becomes yellowish in color. Stunted growth of the plant and premature leaf drop.
Sulphur (S): Available to plant in the form of (SO_4^{2-}) ion.	Sulphur is an essential constituent of amino acids that helps in forming plant proteins. It helps in improving root growth seed production and enhances the formation of oil.	It causes younger leaves turn uniformly yellowish green. Slow stunted growth of the plant ad steam becomes woody and small in diameter.
Boron (B): Available to plant in the form of (H_3BO_3).	Boron is essential in the cell wall of the plant. It enhances seed and fruit development. It helps in regulating the moment of sugar starch Nitrogen and Phosphate.	Death of terminal bud of younger leaves become chlorotic, curled in shape, and brittle. Stunted root growth of the plant.

Iron (Fe): Available to plant in the form of (Fe^{2+}), and (Fe^{3+}) ions.	Iron is useful for the formation and maintenance of chlorophyll. It is an essential part of the enzyme system involved in oxidation and reduction system in photosynthesis.	Iron deficiency occurs in younger leaves. Interveinal chlorosis of the younger leaves and leaves may become white.
Manganese (Mn): Available to plant in the form of (Mn^{2+}), and (Mn^{3+}) ions.	Manganese is an essential constituent of the plant enzyme which helps in protein synthesis. It is involved in the activating enzyme and metabolism of nitrogen.	Manganese is immobile in the plant and deficiency causes the yellowing of the younger leaves between the veins. It hampers the plant size and reduces the yield of fruit production.
Zinc (Zn): Available to plant in the form of (Zn^{++}) ion.	Zinc is an important component in several metalloenzymes which helps to regulate plant growth and utilization of the nitrogen phosphorous in the plant.	Interveinal chlorosis of younger leaves. It produces mottled and extremely small leaves. Deficiency also causes the malformation of fruit.
Molybdenum (Mo): Available to plant in the form of (MoO_4) ion.	Molybdenum is essential for nitrogen fixation in legumes. It helps in the synthesis of protein.	Older and middle leaves become chlorotic, thick, and brittle, and weathering occurs. It causes mottled leaves and leads to curling.
Chlorine (Cl): Available to plant in the form of (Cl^{-}).	Chlorine is essential in the stimulation of photosynthesis. It is useful in the prevention of several fungal diseases. Stimulates some enzymes and regulates the water holding capacity of cell tissues.	Deficiency causes chlorosis of the younger leaves and wilting of the plant.
Copper (Cu): Available to the plant in the form of (Cu^{++}) ion.	Copper is useful in the production of chlorophyll, it acts as a catalyst in respiration.	Stunted growth of the plant. Death of terminal bud of the older leaves.

3.4 Application of fertilizer

Fertilizer plays important role in the nourishment of the crop. For efficient crop management correct fertilizer application is critical for plant growth and to ensure maximum yield. Fertilizer is available in solid granules and in liquid form. The methods of application of both differ from each other.

- The application methods of **solid fertilizers** are broadcasting, placement, band placement, and pellet application.

- The application of **liquid fertilizers** could be through starter solution, foliar application, injection into the soil as well as fertigation.

3.5 Method of fertigation

The method of application of fertilizer along with irrigation water is termed fertigation. This is an advanced system for the application of fertilizer at a controlled rate which helps in providing essential nutrients directly to the root zone of the crop. In this method, fertilizer is liquified with water and distributed along with drip irrigation or sprinkler irrigation system. Sometimes few pesticides and herbicides or other chemicals are also applied along with irrigation, this is commonly termed chemigation.

3.6 Fertilizers suitable for fertigation

Different types of fertilizers - both solid and liquid are suitable for fertigation depending on their specific characteristics such as:

1. It must be completely soluble in water.
2. It should be safer to use.
3. Fertilizer compatibility: It should not react with other water elements or minerals of calcium and magnesium.
4. It should not change the pH of water which tends to cause clogging of emitters.
5. Fertilizer used should avoid corrosion of the irrigation system.

3.7 Main fertilizers used for fertigation

- **Nitrogen:** Most commonly used fertilizer in the fertigation system is nitrogen, almost all the forms of nitrogen fertilizer are suitable except, Ammonium sulphate which tends to increase pH level. The increased pH results into the formation of insoluble calcium and magnesium carbonates that can impede the drip irrigation system. Urea and a mixture of Urea ammonium nitrate are highly suited fertilizers. It can dissolve easily in non-ionic form and does not react with other substances in the water.
- **Phosphorus:** Phosphorus fertilizer is not recommended for application with pressurised irrigation system due to its tendency to cause the clogging problem in drip irrigation systems although sulphuric acid applied along with phosphoric acid can reduce the clogging effect and prevent accumulation of calcium and magnesium in the system.
- **Potassium:** Potassium fertilizer is water soluble and can be mixed with all water-soluble fertilizers, other than calcium-containing fertilizers. It also helps in lowering pH as well as reduces the leaching losses of the Soil. Potassium chloride, potassium sulfate, and potassium magnesium sulphate are suitable for application through the irrigation system

- **Micronutrients:** Tracer elements primarily cause clogging in the drip irrigation system, as they tend to react with salt in water. However more soluble chelated form is suitable for fertigation as it usually causes little clogging problem.

3.7.1 Characteristics of fertilizers

The fertilizers applied in fertigation should be suitable and compatible with the system and ensure good mobility in the soil along with irrigation.

- **Solubility:** The quantity of fertilizer that can be dissolved in a unit quantity of water is called solubility. Normally nitrogen and potassic fertilizers do not have solubility problems. However, phosphatic fertilizers such as DAP & SSP do not readily dissolve in water. The solubility is greatly affected by temperature variations. The solubility decreases with a decrease in temperature.
- **Compatibility:** Mixing the solutions of two or more two water-soluble fertilizers can sometimes result in the formation of a precipitate. Their solutions should be prepared in two separate tanks. The compatibility of different water-soluble fertilizers has been given below:

Table 3.2 : Compatibility of different water soluble fertilizers

Fertilizers	Urea	Ammonium Nitrate	Ammonium Sulphate	Calcium Nitrate	Mono-Ammonium Phosphate	Mono-Potassium phosphate	Potassium Nitrate
Urea		C	C	C	C	C	C
Ammonium Nitrate	C		C	C	C	C	C
Ammonium Sulphate	C	C		LC	C	C	LC
Calcium Nitrate	C	C	LC		NC	NC	C
Mono-Ammonium Phosphate	C	C	C	NC		C	C
Mono-Potassium phosphate	C	C	C	NC	C		C
Potassium Nitrate	C	C	LC	C	C	C	

Note: C = Compatible, NC = Not Compatible, LC = Limited Compatible

Common fertilizers suitable for fertigation purposes have been graded as per suitability and given below:

Table 3.3 : Common fertilizers suitable for fertigation

Property	NH_4NO_3	$(NH4)_2SO_4$	K_2SO_4	KCl	KNO_3	H_3PO_4	MAP
Solubility	High	Medium	Low	Medium	Medium	High	Medium
Precipitation	Low	High	High	Low	Low	Low	High
Compatibility	Good	Poor	Poor	Medium	Medium	Medium	Good
Corrosion	Medium	Poor	Poor	Poor	Good	Poor	Medium

3.8 Factors for consideration in fertigation

The fertilizer application rate should be precisely selected as per the crops according to the uptakes, as its changes according to the rate of plant growth and its stages. Fertilizer recommendation for any soil and crop should be determined according to its soil properties, e.g. soil type, pH, nutrients concentrations and cation exchange. The increased presence of fertilizers in the soil adversely affects the absorption of both the water as well as nutrients. For example, the chloride increases the osmotic pressure, sulphates develop toxic effect on the plants. Higher concentration of fertilizers in the soil can be detected by noting root injury, burning of leaf tips etc. The quality of irrigation water should also be considered for its pH, EC and presence of excessive salts etc

3.9 Advantage of Fertigation

1. Uniform and precise application of fertilizer to active root zone, this improves fertilizer use efficiency and reduces leaching losses.
2. Nutrient supply can be regulated in number of splits as per plant requirement.
3. Macro and micro nutrients can be applied in one solution to the plant.
4. Safer application methods ensure eliminating danger of burning crop root zone.
5. It saves time, labor and energy.
6. Higher yield and better quality of produce obtained.

3.10 Limitation of Fertigation

1. Higher initial investment.
2. It needs water soluble fertilizer or liquid fertilizer.
3. It required good quality water as poor-quality causes clogging of emitters.
4. Corrosion free fertigation equipment are needed.
5. Technical knowledge and skills of operator/farmer are required.

3.11 Common considerations in fertigation

The following points should be considered in operation of fertigation system.

1. The fertilizers to be used should be water soluble.
2. The fertilizers should be injected at the upstream end of the filters to ensure that any undissolved particles of the fertilizers/chemicals are removed before entering in to the system.
3. The irrigation system should be pressurized before starting the process of fertigation.
4. The system should be equipped with the anti-siphon device to protect the water supply from contamination of the fertilizers.
5. The uniformity of water application should be high, so that it ensures uniform application of the chemicals.

3.12 Precautions

The following safety precautions should be observed for successful fertigation system.

1. Do not inject fertilizers in combination with pesticides or chlorine.
2. Back siphonage, back pressure or back flow should not occur and best practices to avoid these should be followed.
3. Operating pressure variations should be minimum in order to achieve uniform mixing of nutrients and irrigation water in the drip irrigation system.
4. Compatibility of two fertilizers should be checked to avoid precipitation that may cause clogging of drip emitters and filter system.
5. To eliminate entry of solid particles or undissolved fertilizers a small screen/ strainer should be placed at the end of suction line.
6. Adjustment of the water pH should be made as per the pH of fertilizer solution.
7. The fertilizer injection point must be at the upstream end of the filter system.
8. Irrigation and fertilizer injection pumps should be compatible to prevent entry of fertilizer in the irrigation line.

3.13 Stock solution

In the fertigation process, nutrient solution is applied through pressurised irrigation system. For this purpose, a concentrated solution is prepared in a separate fertilizer storage tank. These concentrated solutions are known as stock solution or mother solution. This solution can be prepared in various tanks and number of tanks required for this purpose depends upon the type of fertilizer applied and its compatibility, and solubility of the fertilizer. Some fertilizers can be reacted with the water elements and causes clogging in the irrigation system.

3.14 Equipment of Fertigation

Fertilizers are injected into pressurised irrigation system by selecting a wide variety of pumps or fertilizer tanks or venturis. In addition to components of pressurised irrigation system (Drip/sprinkler irrigation), the equipment used to apply fertilizer in pressurised irrigation system, includes a fertilizer tank, fertilizer dissolver, fertilizer injected devices, a pressure gauge, check valves, and pressure regulators. The stock solution is applied at a predefined injection rate through the above pre-calibrated injection devices.

Stock Tank: The stock tank (Fig. 3.1) is used to store stock solutions. It should have sufficient storage capacity to contain the entire fertilizer solution required for the application. The stock tank is made up of epoxy-coated material to withstand the corrosivity of fertilizers.

Fig. 3.1: Stock Tank

Fertilizer injector devices: In fertigation, fertilizer is applied through a pressurised irrigation system for injecting fertilizers from the storage tank to the irrigation water injector are required. Basically, the injectors are designed on two basic concepts:

a) **Proportional Concept**: The amount of fertilizer application is based on the rate of discharge of water. It enables the application of constant concentration of the fertilizer. Venturi pump and fertilizer injection pump is based on this concept.
b) **Quantitative Concept:** The calculated application of fertilizer is applied to the given area, the amount of solution decreases with the irrigation process, and fertilizer injection is not proportional to the water discharge rate. A fertilizer by-pass tank works on this principle.

There are many ways to inject fertilizer into an irrigation system three principal methods to inject fertilizer in the pressurised system are a pressure differential fertilizer tank, a venturi injector, and a fertilizer injection pump.

1. Pressure differential fertilizer tank system

This is the simplest method of injecting fertilizer into the irrigation system (Fig. 3.2). It operates on the principle of differential pressure created by a regulating valve between the tank inlet and outlet. The pressure at the inlet of the tank is higher than the pressure at the outlet of the tank. A sealed airtight pressure tank is required to withstand maximum operating pressure which is connected to the irrigation pipe at the supply point. The small quantity of irrigation flow is diverted through the tank entering at the bottom it diluted the fertilizers and returns to the main supply Pipe. The main disadvantage of this method is that the uniform application of nutrients cannot be monitored and regulated as well as a tank required refilling of fertilizer frequently.

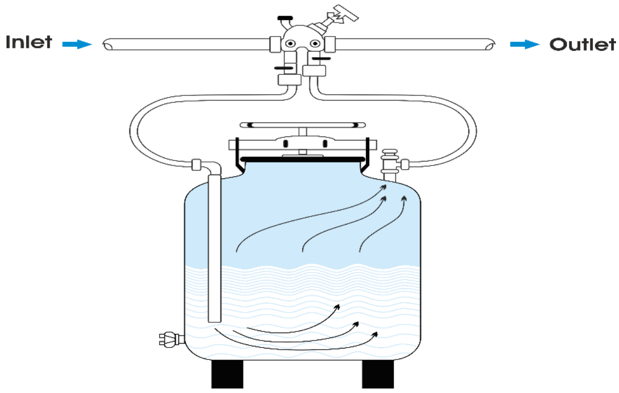
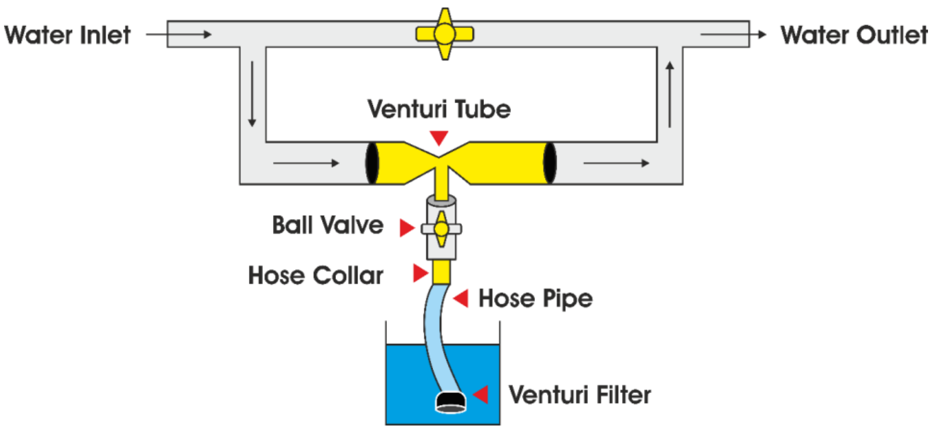


Fig. 3.2: Fertilizer Tank

Venturi injection system

This method is based on the principle of venturi. A venturi injection system (Fig. 3.3) consists of a converging section, diverging section and a throat. Venturi injector uses excess pressure in the irrigation system regulated through pressure regulating valves to create pressure decline in the throat section, which is sufficient enough to suck fertilizer solution into the irrigation system. The rate of injection depends upon the pressure difference while small change in pressure hampers the injection rate.



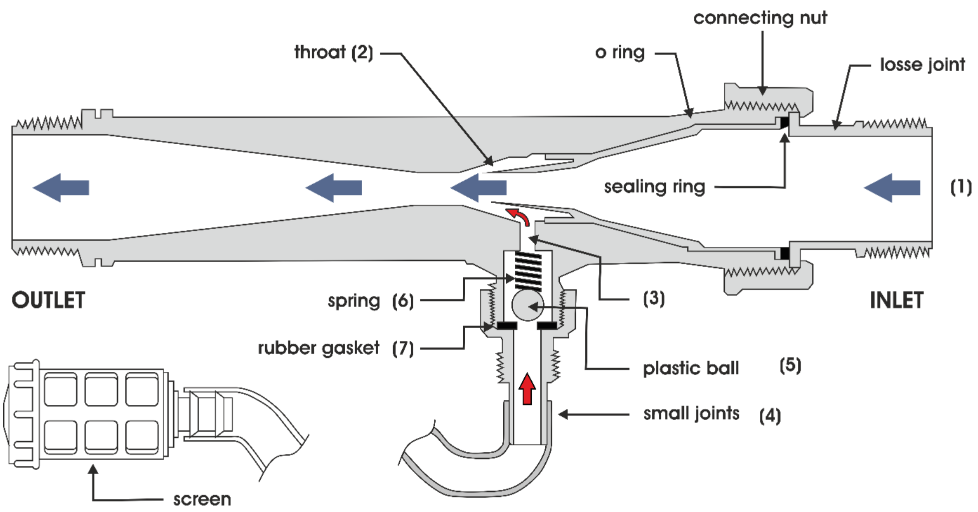


Fig. 3.3: Venturi Injection System

Fertilizer Injection Pump: This method uses a pumping system to draw fertilizer solution from the storage tank and injected it into the irrigation system (Fig. 3.4). Injector energy can be driven by various means such as electric motors, internal combustion engines, and water-driven hydraulic motors. A hydraulic pump is more versatile and economical for use, the piston pump injector is driven by the water pressure of the system and the rate of injection is proportional to the flow of water. In this type of pump, the desirable rate of injection is regulated by adjusting the length of the stroke of the piston. The main advantage of this system is that it can apply a constant amount of fertilizer solution throughout the period irrigation cycle. It does not add head loss to the irrigation system. Higher maintenance and equipment costs are the main drawbacks of this injector.

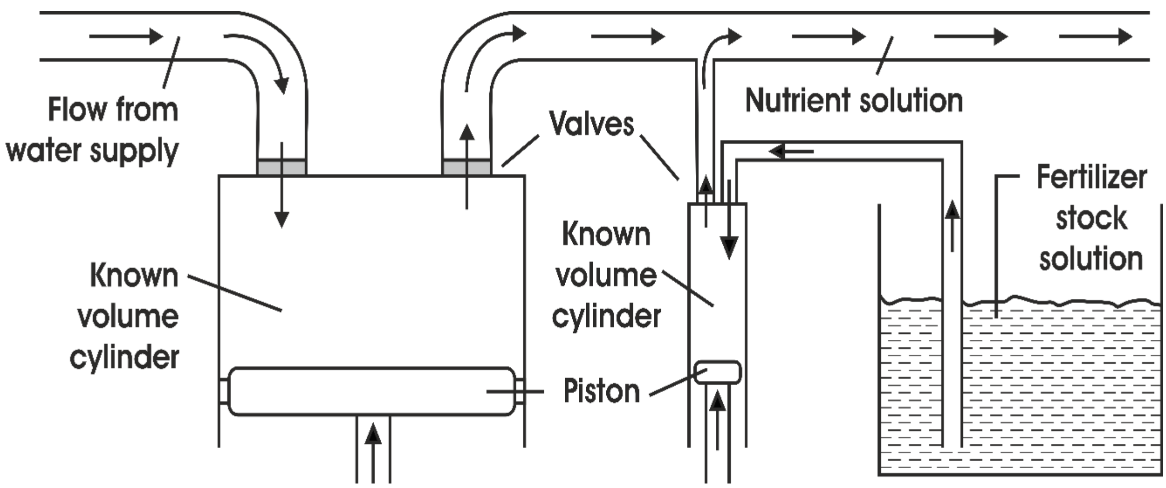


Fig. 3.4: Fertilizer Injection Pump

Frequency of Fertigation: Fertigation can be operated at desirable frequencies like with every irrigation or alternatively with the irrigation. The frequency of fertigation depends upon the nutrient requirement of the plant, soil type, and irrigation scheduling. It is also important to consider leaching losses due to excess application of the nutrients.

Injection Duration: The injection duration of the fertilizer in the fertigation system depends upon the soil type, irrigation duration, minimum desirable concentration, and nutrient requirement of the plant. Generally, during the first and last quarter of irrigation duration, plain irrigation water is applied, whereas, fertigation should be applied during the second and third quarter of the duration of irrigation. The duration of injection of the fertilizer should be sufficient enough to distribute nutrients uniformly to the entire field.

Fertilizer Salt Index: The fertilizer salt index is a measure of salt concentration induced in a soil solution. A salt index is a numerical value expressed as a ratio in which the selected fertilizer product is compared to the same weight of sodium nitrate ($NaNO_3$), where sodium nitrate is assigned a value of 100. Sodium nitrate is used for comparison because it was widely available when the salt index was developed and because it is 100 percent soluble in water.

Salt Index (SI): Salt content is one of the most critical characteristics of fertilizers used for row-seed placement. The SI is a measure of the salt concentration that fertilizer induces in the soil solution.

The SI of a material is expressed as the ratio of the increase in osmotic pressure of the salt solution produced by a specific fertilizer to the osmotic pressure of the same weight of $NaNO_3$, which is based on a relative value of 100. Sodium nitrate was chosen as the standard because it was 100 percent water soluble and it was a commonly used nitrogen fertilizer when the SI concept was first proposed in 1943. Higher analysis fertilizers usually have a lower SI because fewer ions of salts are placed in the soil solution per unit of plant nutrient when they dissolve.

Note that the N and K materials of commonly used fertilizers (Table no. 02) have higher SI values than those of P materials. The SI of a mixed formulation containing N, P, and/or K is the sum of the SI values of its components. Although the total SI for a high-analysis NPK mixture may be greater than that for a low-analysis NPK mixture, the SI per unit of plant nutrients may be lower in the high-analyses product. Therefore, the lower fertilizer rate needed to supply the same amount of plant nutrients subjects the germinating seeds to less potentially adverse salt effects (Table 3.4).

Table 3.4 : Salt index values of fertilizer materials

Material and analysis	Salt Index: Per equal wts. of materials	Salt Index: Per unit of nutrients*
Nitrogen/Sulfur		
Ammonia, 82% N	47.1	0.572
Ammonium nitrate, 34% N	104.0	3.059
Ammonium sulfate; 21% N, 24% S	68.3	3.252
Ammonium thiosulfate, 12% N, 26% S	90.4	7.533
Urea, 46% N	74.4	1.618
UAN, 28% N (39% am. nitrate, 31% urea)	63.0	2.250
32% N (44% am. nitrate, 35% urea)	71.1	2.221
Phosphorus		
APP, 10% N, 34% P_2O_5	20.0	0.455
DAP 18% N, 46% P_2O_5	29.2	0.456
MAP 11% N, 52% P_2O_5	26.7	0.405
Phosphoric acid, 54% P_2O_5		1.613**
72% P_2O_5		1.754**
Potassium		
Monopotassium phosphate, 52% P_2O_5, 35% K_2O	8.4	0.097
Potassium chloride, 62% K_2O	120.1	1.936
Potassium sulfate, 50% K_2O, 18% S	42.6	0.852
Pot. thiosulfate, 25% K_2O, 17% S	68.0	2.720
** Salt index per 100 lbs of H_3PO_4	* One unit equals 20 lb.	

It should be noted that the SI does not predict the exact amount of fertilizer material or a fertilizer formulation that could produce crop injury on a particular soil. However, it does compare one fertilizer formulation with others regarding the osmotic (salt) effects. It also shows which fertilizers (those with a higher SI) will be most likely to cause injury to germinating seeds or seedlings if placed close to or in the seed row.

Calculating Salt Index: The SI of a mixed fertilizer (NPKS) is the sum of the SI of each component per unit of plant nutrient times the number of units in that component. See Table no. 03 for SI calculations of 7-21-7.

To calculate SI of any formulation (Table 3.5):

1. List the material, grade, and weight for each component in columns 1-3.
2. Determine nutrient units in columns 4-6 by multiplying the weight of each component by its nutrient content and dividing each result by 20.
3. List SI per plant nutrient unit in each component in column 7.

4. Determine the SI due to each component by multiplying the sum of the nutrient units in columns 4-6 times the corresponding SI value in column 7.
5. Total individual SI values of all components in column 8.

Table 3.5: Calculating salt Index of 7-21-7

Salt Index							
			Nutrient units			Per unit (20 lb)[a]	In formulation
Material	**% Nutrient**	**Lbs/ton**	**N**	**P_2O_5**	**K_2O**		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
10-34-0	10%N, 34% P_2O_5	1235	6.2	21.0	-	0.455	12.4
UAN	28% N	57	0.8	-	-	2.250	1.8
KCl	62% K_2O	226	-	-	7.0	1.936	13.6
Water	-	482	-	-	-	-	-
Total		2,000	7.0	21.0	7.0		27.8[b]

[a] Salt index per unit (20 lb) of plant food nutrients, listed Table 1, also called the partial salt index.
[b] 0.79 SI/unit plant nutrient

SI values for a 6-24-6 formulation containing potassium phosphate are shown in Table 3.6. Phosphoric acid is first ammoniated to a 1-3-0 ratio, which results in an approximate 50-50 mixture of MAP and DAP at about pH 6.8. Potassium phosphate is then added to provide all of the K and the remainder of the P Resulting SI of this grade and SI per unit of plant nutrients are much lower than those for 7-21-7, which contained KCI.

Table 3.6: Calculating Salt Index of 6-24-6

Salt Index							
			Nutrient units			Per unit (20 lb)[a]	In formulation
Material	**% Nutrient**	**Lbs/ton**	**N**	**P_2O_5**	**K_2O**		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NH_3	82% N	146	6.0	-	-	-[b]	-
H_3PO_4	54% P_2O_5	666	-	18.0	-	1.613	10.7
Potassium phosphate	22% K_2O, 22% P_2O_5	546	-	6.0	6.0	0.097	1.2
Water	-	642	-	-	-	-	-
Total		2,000	6.0	24.0	6.0		11.9[c]

a. Salt index per unit (20 lb) of plant food nutrients, listed Table 1, also called the partial salt index.
b. Ammonization of phosphoric acid to a 1-3-0 ratio forms a mixture of MAP and DAP.
c. 0.32 SI/unit plant nutrient.

Other points to consider are: When K_2SO_4 is used instead of KCI, the SI is somewhat lower. However, the solubility of K_2SO_4 is lower than that of KCI, so this must be considered in producing formulations relatively high in K_2O. SI values of acids are given as values per 100 lbs of acid rather than a unit of 20 lbs. Also, the SI of H_3P0_4 varies with P concentration of the acid.

SI values calculated differ for formulations when ammoniated phosphate solutions are prepared. SI per unit of N due to the ammoniating solution is not included because its contribution has already been accounted for in the SI per 100 lbs of H_3PO_4, since it has been converted to ammonium phosphate. The same method is used for calculating the SI of ammoniated H_2S0_4 formulations. SI values and SI per plant nutrient of some commonly used liquid formulations are listed in Table no. 05. Note that all formulations containing potassium phosphate have relatively low SI values. The two formulations containing KCI (7-21-7 and 4-10-4) have much higher SI values and are not suggested for use in seed-row placement. These results show that SI of fluid fertilizers varies significantly, depending on the grade and components in the formulation (Table 3.7).

Table 3.7: Salt index of some common liquid formulations

Formulation	Salt index	Salt index per unit of plant nutrient (20 lb)
2-20-20[a]	7.2	0.17
3-18-18[a]	8.5	0.22
6-24-6[a]	11.5	0.32
6-30-10[a]	13.8	0.30
9-18-9[a]	16.7	0.48
10-34-0[b]	20.0	0.45
7-21-7[c]	27.8	0.79
4-10-10[c]	27.5	1.18
28% UAN[c]	63.0	2.25

a. These grades are formulated using potassium phosphate as the K source.
b. Use in seed-row with caution.

ACTIVITIES

Activity 01: Enlist the name of macro and micronutrients.

Procedure

Write down the function and deficiency of the essential macro and micronutrients of the plant.

Activity 02: Visit the local market and collect information about various fertilizers available along with their nutrient composition.

Material required

1. Pen
2. Notebook

Procedure

1. Locate the fertilizer shop in the market.
2. Ask about the various fertilizers available in the market.
3. Note down the information provided by the leaflet or shopkeeper.
4. Make a list of water-soluble and insoluble fertilizers.

Activity 03: List various fertilizer application methods.

Material required

1. Pen
2. Notebook

Procedure

1. Draw a flow chart of the fertilizer application method.
2. Write a brief note on various fertilizer application methods.

Activity 04: Draw a sketch/ working principle of the fertilizer tank, venturi meter, and fertilizer injector pump.

Material required

1. Pen
2. Notebook

Procedure

1. Enlist the various equipment used in the fertigation system.
2. Draw a sketch of the fertilizer tank, venture meter, and fertilizer injector.
3. Write down the working principle of the fertilizer tank, venture meter, and fertilizer injector pump

Activity 05: Collect the specification of the venturi meter and other fertilizer

injectors from the market.

Material required

1. Pen
2. Notebook

Procedure

1. Visit the market and identify the local dealer shop of a standard equipment provider company.
2. Ask for specifications of the venturi meter and other fertilizer equipment from the dealer.
3. Collect the pamphlet and write down the specifications of the equipment.

CHECK YOUR PROGRESS

A. Answer the following question

1. Define the term nutrient and also write their types.
2. List the function and deficiency of plant nutrients.
3. Explain the role of fertilizer for crops.
4. Describe the methods of fertigation.
5. What are the main fertilizers used for fertigation?
6. Explain the characteristics of fertilizers.
7. Write the advantage and disadvantages of fertigation.
8. Enlist the name of the equipment used in fertigation.

B. Fill in the blank

1. Excessive fertilizer application increases the ……… of fertigation and labour requirements.
2. …………… are vital in the overall development of the plant.
3. Manganese is an essential constituent of the plant enzyme which helps in ………… synthesis.
4. The frequency of fertigation depends upon the …………….. requirement of the plant, soil type, and irrigation scheduling.
5. The fertilizer ………….. is a measure of salt concentration induced in a soil solution.
6. The irrigation system should be pressurized before starting the ………….. of fertigation.

C. Match the following

Column A	Column B
1. It is useful for the formation and maintenance of chlorophyll. It is an essential part of the enzyme system involved in oxidation and reduction system in photosynthesis.	A. Manganese
2. It is an essential constituent of the plant enzyme which helps in protein synthesis. It is involved in the activating enzyme and metabolism of nitrogen.	B. Chlorine
3. It is an important component in several metalloenzymes which helps to regulate plant growth and utilization of the nitrogen phosphorous in the plant.	C. Iron
4. It is essential for nitrogen fixation in legumes. It helps in the synthesis of protein.	D. Zinc
5. It is essential in the stimulation of photosynthesis. It is useful in the prevention of several fungal diseases. Stimulates some enzymes and regulates the water-holding capacity of cell tissues	E. Copper
6. It is useful in the production of chlorophyll, it acts as a catalyst in respiration.	F. Molybdenum

Module 4	Operation and Maintenance of Micro-Irrigation Systems

Module Overview

This module covers the operation, maintenance, and troubleshooting of micro-irrigation systems, including sprinkler and drip methods. Learners will discover how to effectively operate these systems, maintain essential components like filters, and resolve common issues such as blockages and damage. The module also highlights the importance of system flushing, chemical treatments, and strategies to prevent problems caused by rodents and animals, equipping learners with skills for maintaining efficient and long-lasting irrigation systems in agriculture.

Learning Outcomes

After completing this module, you will be able to:

- Operate micro-irrigation systems, including sprinkler and drip irrigation methods, effectively.
- Understand the procedures for maintaining and troubleshooting sprinkler irrigation systems.
- Diagnose and resolve common issues in sprinkler irrigation systems.
- Execute the proper operation of drip irrigation systems for optimal performance.
- Perform flushing of irrigation systems and their components to prevent blockages.
- Maintain and clean filters to ensure uninterrupted water flow.
- Apply chemical treatments to address irrigation systems' scaling, biofouling, and algae growth.

Module Structure

4.1 Operation of micro-irrigation system: The most efficient operation of the micro-irrigation system depends upon the ability of the user to use the best of it. The micro irrigation system runs on several inputs and involves certain physical processes like energy transformation; friction, pressure phenomenon etc. All the components of micro irrigation continuously undergo the mentioned processes and phenomenon. Routine maintenance involves "preventative" practices that all micro-irrigation systems should receive regardless of age. Proper attention to the following will decrease the likelihood of irrigation system failure. The key factor for the most efficient irrigation management is the knowledge of operation and maintenance for the system. Any fault or flaw in the irrigation system can preliminarily be monitored by change in pressure and discharge at a given location. Although the discharge generally in proportion to the pressure, still very high pressure built-up or extreme drop in pressure may result in physical damage and very poor performance of the irrigation system respectively.

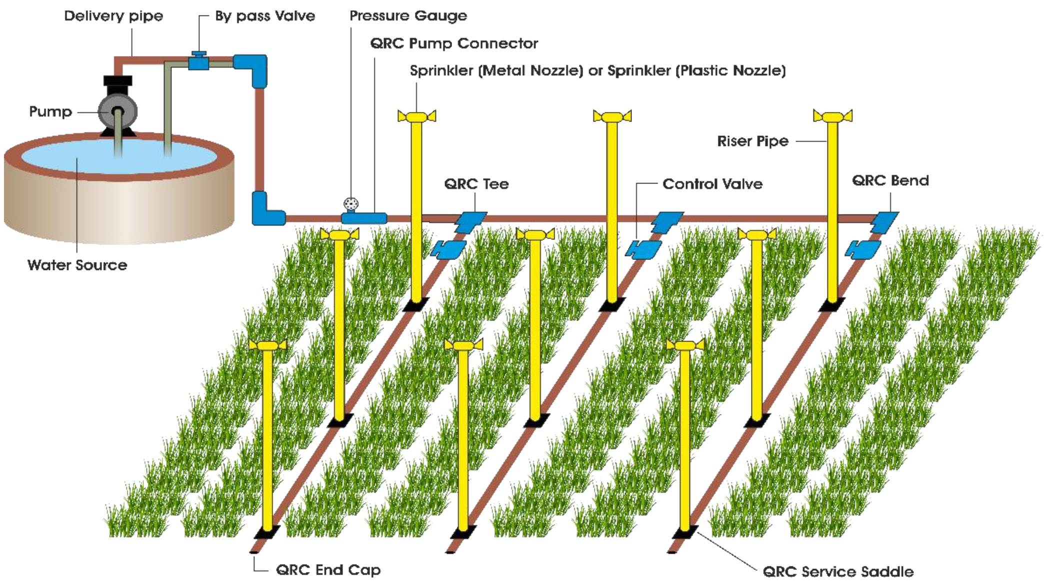


Fig. 4.1: View of micro-irrigation system

Pressure monitoring device

The irrigation system operates within the designed range of pressure called the working pressure. Pressure can be measured by using suitable devices lika e manometer or pressure gauge connected directly or by using pitot tube. When the system is in operation, measurements of pressure at various points on the pipe network have to be taken, preferably at the beginning and at the far end of the main and the submain pipelines. The actual pressure should be within the permissible design pressure range. The operating pressure of the first and last emitters on random of laterals line has also to be measured after some time has been elapsed. The recommended average pressure difference in the emitters should not be more than 20 percent. Any change should be investigated immediately.

Fig. 4.2: Common type of pressure gauge

Flow monitoring device

During operation the flow rates (discharge) at different points of mains and submains have to be observed using flow meter. A suitable flow meter should be installed at the desirable location, preferably before the fertigation equipment at the head works. Similarly, for emitters the flow rate could be determined by volumetric and time basis. The figure should be in accordance with the supplier's specifications and the difference between them should be less than 10 percent. Uniformity of application is also determined by observing the variation of discharge of random emitters in the system. The discharge of system is the sum of the sprinkler heads or emitters' flow rates.

Fig. 4.3: Water meter

4.2 Operation and maintenance of sprinkler irrigation systems

The sprinkler irrigation system has to be operated only with the pressure built up in the system attains design or required pressure range. This can be achieved by starting the pump with free flow of water all through the pipe network to release all the air in the network and avoid vacuum. With the successful release of air, the valves at the end of the system as well as the submains have to be closed. This enables to build up the rated pressure required for the operation of the installed sprinkler heads. Once the pressure is attained to operational limit the valves at the submains are opened to start the operation. For smooth operation of sprinkler system, following steps may be adopted:

1. Inspect all the valves location and open all the end caps and flush valves to release any clogging material present in the system.

2. Start the pump and release the water throughout the pipe network and observe for any leakage or breakage in the joint or pipelines respectively.
3. Fix the fault and close all the valves located at the end of the system as well as that at the submain, so that the pressure in the system attains the design range.
4. Once the limit is achieved open the valves of the submains to start the operation.
5. Check the pressure and discharge of the system periodically.
6. Operate the system according to the irrigation schedule for efficient irrigation application.

4.2.1 Do's and don'ts of sprinkler irrigation system

Do's

1. Use the same type of sprinkler heads throughout the system.
2. Perform routine checks of each sprinkler discharge to monitor the uniformity of application.
3. If there is variation in discharge look for any leakage in the system and modify it.
4. Check the spacing of the sprinkler for the design pressure to avoid the wastage of water.
5. Operate the system following an irrigation schedule.

Don'ts

1. Don't use heads of different discharge and/or pressure rating.
2. Don't use sub mains, riser pipes of different sizes or length.
3. Don't operate the system at excessive pressure limits as lower pressure increases water droplet size and high pressure reduces the water droplet to fine mist.
4. Do not apply oil, grease or any other lubricant on to the sprinkler heads. They are water lubricated and using oil, grease or any other lubricant may make them defunct.

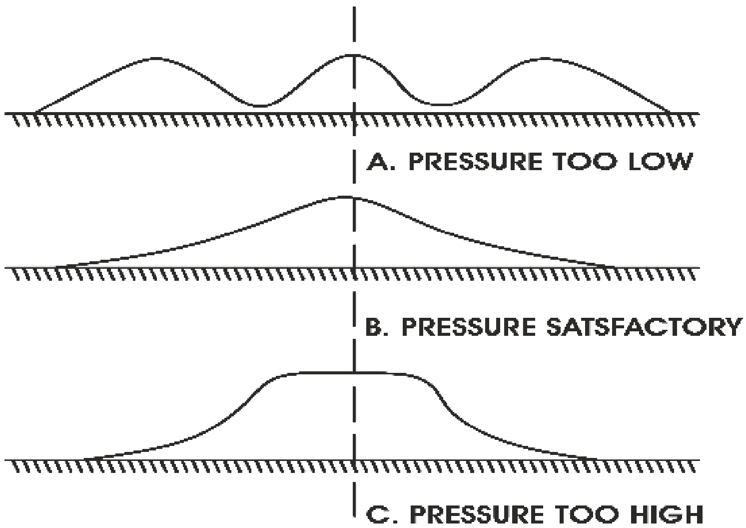


Fig. 4.4: Pressure graph

Table 4.1: Periodic maintenance of the sprinkler system

Frequency	Unit/ Parameter	Action
Daily	**Pressures**	• Check that pump and block pressures are within the prescribed limits.
	Sprinkler head	• Check for clogged, broken or misplaced heads. Repair, replace, and unclog the heads.
	Leaks	• Check for water wastage and leaks in pipes, pipe joints and other equipment, and repair them immediately.
	Primary filter	• Flush or backwash the primary filters as prescribed.
	Fertigation application	• Check that fertigation applications are within specifications.
Weekly	**Exposed joints**	• Check and repair them if needed, e.g., quick coupling rubbers.
	Secondary filters	• Flush or backwash the secondary filters as prescribed.
	System pressure and flow	• Check that the system pressure and flow are as per the irrigation design plan.
	Pump operation	• Check that pump operation is within the prescribed parameters.
	Block pressures for automated valves	• Check that the block pressures are within the prescribed limits where automated valves are used.
	Pump lubrication	• Check the lubrication requirement of the pump as prescribed.
	Fertigation plant	• Inspect the fertigation plant for its smooth functioning.

4.2.2 Maintenance of lateral pipes

Lateral pipes are meant to be checked for maintenance regularly. Steps to be followed for maintenance are:

(i) Inspect the joints from the submain for any leakage, if any, repair the section.
(ii) Check the rubber sealing ring to avoid dirt deposition and damage of coupler.
(iii) Make sure no heavy materials are placed above the pipes.
(iv) Flush the lateral pipes after every operation to release any debris deposition from the water source.

4.2.3 Maintenance of sprinkler heads

(i) When moving the sprinkler risers, make sure that the sprinkler heads are not damaged or pushed into the soil.

(ii) Check the sprinkler nozzle for deposit or blockage and remove if any.

(iii) Do not apply oil, grease or any other lubricant on the sprinklers. They are water lubricated and using oil, grease or any other lubricant may stop them from working.

(iv) Sprinklers, usually, have a sealed bearing and at the bottom of the bearing, there are washers which are maintenance free for any damage.

(v) Usually, it is the washer that wears and tears and not the metal parts. Check/replace the washers for wear and tear once a season or every six months, which is important in areas where the water is sandy.

(vi) After several days of operations, the swing arm spring may require tightening. This is done by pulling out the spring end at the top and rebending.

Table 4.2: Common troubleshooting of pump set

Trouble	Causes
i. No water delivered	• Pump not primed • Suction pipe or inlet pipe leakage • Discharge head too high • Suction head too high • Faulty or damage impeller • Wrong direction of rotation • Vacuum in suction line • (viii) Insufficient net positive suction head available
ii. Not enough water delivered	• Air leak in suction line • Rotational speed too low • Discharge head higher than anticipated • Suction lift too high • Impeller or suction pipe partially plugged • Wrong direction of rotation • Insufficient net positive suction head available • Debris stuck on the foot valve • Insufficient submergence of suction inlet • Bearings worn out
iii. Not enough pressure developed	• Rotational speed too low • Wrong direction of rotation • Viscosity of liquid higher than anticipated • Bearings worn out • Impeller diameter too small

iv.	**Pump works for a while and then loses prime**	• Air leak in suction line or clogging • Suction lift too high • Air pocket in suction line • Water seal tube clogged • Insufficient submergence of suction inlet
v.	**Pump requires excessive power**	• Speed too high • Head lower than anticipated, pumps too much water • Wrong direction of rotation • Misalignment or bent shaft • Stuffing box too tight • Bearings worn out • Rotating element rubbing or binding
vi.	**Pump noisy or vibrates**	• Suction lift too high • Insufficient Net Positive Suction Head (NPSH) available • Impeller or suction pipe partially plugged • Misalignment or bent shaft • Foundation not rigid • Lack of lubrication • Bearings worn out • Rotating element out of balance

4.3 Common troubleshooting of sprinkler

1. Pump does not prime or develop pressure.
   a) Check the suction lift is within limit, if not get pump closer to the water level.
   b) Check the suction pipelines and its joint for air leaks, if required tighten it.
   c) Check for any blockage in the strainer of the foot valve.
   d) Check the direction of the rotation of the pump is correct.
   e) Check for any air leakage in the pump gland. If required tighten.
2. Sprinklers do not turn.
   a) Check the pressure.
   b) Check the nozzle for any blockage.
   c) Check whether the sprinkler bearing is free and smooth.
   d) Check the condition of the washer at the bottom of the bearing.
   e) Check the swing arm spring tension.
3. Leakage from coupler and fittings.
   a) Check for accumulation of dirt and sand in the groove of the coupler.
   b) Check for any distortion of pipe fitted to the coupler.
   c) Check whether all the fitting such as bends, tee and reducers has been properly connected.

4.4 Operation of drip irrigation system

The proper and trouble-free operation may be achieved by considering the following guidelines.

i) Maintain all the design, evaluation and testing information from the designer, installer and dealer handy.
ii) Follow the irrigation schedule in accordance with the climatological data of previous day(s) or from the average historical data.
iii) Conduct regular checking of the pressure at the pressure gauges.
iv) Operate the head valve to begin irrigation.
v) Check all the components for proper operation, beginning with pressure readings at the control header.
vi) Check the emitters, randomly for their smooth discharge.
vii) Measure the emission uniformity of the system at least at the start of the irrigation season.
viii) The chemical and fertilizer injection equipment's to ensure the application of desired quantity and concentration (US Soil Cons. Service, 1984).

4.4.1 Maintenance of drip irrigation system

Reliable performance of a drip irrigation system depends upon the periodic preventive maintenance of all the components of the drip irrigation system. These includes pipe flushing, filed check for leakage, checking of dripper for their discharge and wetting zone, check for clogging in the filters etc.

4.4.2 Periodical maintenance of drip irrigation system

I. Daily maintenance

To maintain efficient irrigation and clogging free operation. Regular maintenance activities of primary filters, secondary filters, laterals and emitters are essential. The following actives may be followed.

1. Perform cleaning of Hydro cyclone and screen filter especially when source of irrigation is borewell or tube well.
2. In case of sand filter (sand filter is used when the source of irrigation is open water source like rivers. canals. wells etc.) perform backwashing is necessary.
3. Check the uniformity in drippers discharge.
4. Check the positions of the dripper, if they are misplaced place then locate proper position.
5. Perform flushing of laterals by removing the endcaps for about 2 minutes
6. Flush the sub-mains via the flush valves to remove the impurities are also accumulated at the end of the sub-mains.

II. Weekly Maintenance

Weekly maintenance means the maintenance activities that has to be conducted once for every one week

1. Sand filter maintenance

Check any pressure difference between the inlet and outlet valves of the sand filter, if any and the pressure difference is greater than 0.5kg/cm^2, then needs cleaning.

2. Screen filter maintenance

Check for accumulation of silt and the fine particles of dirt on the filtering element on the screen filter (mesh in the screen filter). This affects the filtration process. Hence cleaning the filtering element of the screen filter is necessary.

III Monthly Maintenance

Check for clogging and blockage of drippers and lateral respectively due to the salts, algae and other impurities that are present in the irrigation water. Based on the observation of problem maintenance with acid or chlorine treatments can be performed once in a month.

Seasonal Maintenance

1. Replace the media of the sand filter with the new.
2. Replace the components with the spare parts where ever necessary.
3. Provide adequate lubrication to the pump and the motor. Follow the maintenance activities for pump as prescribed by the pump manufacturer.

4.5 FLUSHING OF SYSTEMS AND ITS COMPONENTS

Silt or other fine dirt materials can escape through the filters and settles in sub mains and laterals. Also, some algae and bacteria lead to the formation of slimes/pastes in the sub mains and laterals. The accumulation and slime formation on sub mains should be flushed by opening the flush valves. Flushing can be done by removing the end caps of laterals and submain allowing water to pass through. The flushing process should be completed once the flushed water exiting is cleaned.

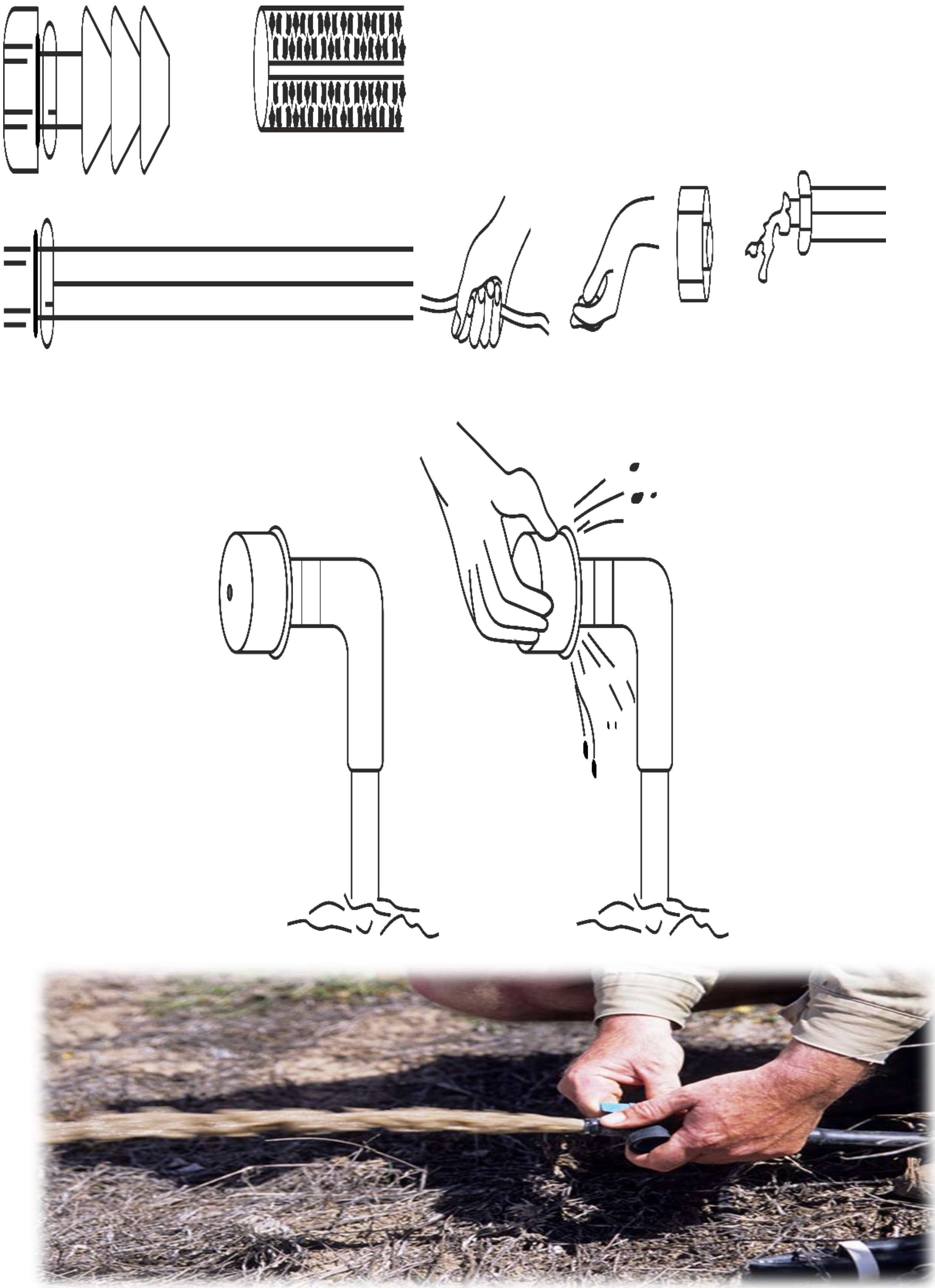


Fig. 4.4: Flush

4.6 MAINTENANCE OF FILTER

Filter is the heart of a drip irrigation system and its failure will lead the poor performance of and in turn. Pressure difference in the system is due to clogging of the emitters across the filter and it indicates the time for cleaning of the filter.

i) Hydro Cyclone Filter

Hydro cyclone filter should be installed before sand and screen filter in case there is heavy load of sand in irrigation water. Hydro cyclone filter requires least maintenance; however, the dirt or sand, inside the under-flow chamber should be removed daily. Flush the chamber by opening flush valve/cap are or open the main valve for thorough cleaning.

ii) Sand Filter

The sand filter should be backwashed every day for removal the silt other dirt or any other organic matter accumulated. During back washing, the backwash water should be allowed to pass through the lid instead of the backwash valves. The sand in the filter bed is stirred up to the filter candles without damaging them and the dirt accumulated deep inside the sand bed will get free and goes out with the water through the lid.

Fig. 4.5: Sand filter

iii) Screen/Disc Filter

Screen and disc filters have to follow the daily scheduled maintenance necessarily. It is recommended to flush the screen filter, if pressure drops more than 0.5 kg/cm^2. The cleaning of the Screen / Disc filter is done before the start of the irrigation system by opening the flushing valve of the filter link to flush out the dirt and silt. The filter element (screen or disc) should be taken out from the filter and cleaned in flowing water. The rubber seals on both sides are also removed and again placed properly in the position to avoid damage.

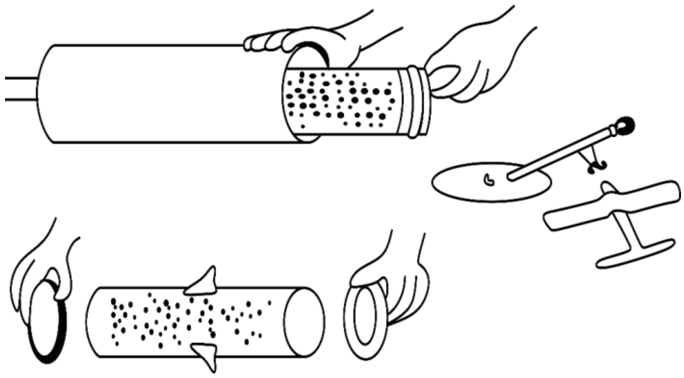


Fig. 4.6: Screen filter

4.7 CHEMICAL TREATMENTS

The drip irrigation system often faces clogging or plugging of emitters/orifices due to precipitation and accumulation of certain dissolved salts like carbonates, bi-carbonates, iron, calcium and manganese salts. This clogging or plugging can be removed by chemical treatment which include application of chloride and/or acid with water. Chlorine treatment is required to remove organic and any physical materials and acid treatment is required to remove the salt and any chemical precipitates from the system.

i) Acid Treatment: In acid treatment, Hydrochloric acid is injected into the drip irrigation system at the recommended rate. The acid transfusion is performed till a pH of 4 is achieved at the end of pipe and after that the system is shut off for 24 hours. After one day halt the system is flushed by opening the flush valve and lateral end caps.

ii) Chlorine Treatment: Chlorine in the form of bleaching powder is used in the treatment to inhibit the growth of microorganisms like algae and bacteria. The treatment is performed by mixing beaching powder or by injecting chlorine solution and left the system to shut off for 24 hours. After one day halt the lateral end caps and flush valves are opened to flush out the water with impurities.

Table 4.3: Troubleshooting

S.No.	Problems	Causes	Remedies
1.	Leakage of water at the joint between sub main and lateral	Damaged joints	Correct damages
2.	Leakage in the poly tube	Damage of poly tube by farming activities/rat	Block the holes by Goof plug. Use poly joiners at cuts.
3.	Water not flowing upto the lateral end	Holes in laterals. Cuts in laterals. Bents in laterals.	Close the holes and cuts. Remove the bends.

4.	Outcoming of the white mixture on removing the end plug	More salinity in water. Uncleaned lateral	Remove the end stop. Clean the laterals fortnightly
5.	Underflow or overflow from laterals	Clogging of drippers. Unclosed end plug	Clean the sand and screen filters. Close the end cap
6.	Oily gum material comes out on opening the lateral end	More algae or ferrous material in water	Clean the laterals with water or give chemical treatment
7.	Oily gum material comes out on opening the lateral end	More algae or ferrous material in water	Clean the laterals with water or give chemical treatment
8.	More pressure drop in filters	Accumulation of dirt in ers	Clean filters every week. Back wash the filters for every 5 minutes daily.
9.	Pressure gauge not working	Rain water entry inside. Corrosion in gauge pointer damage	Provide plastic cover and fix pointer properly.
10.	Drop in pressure	Leakage in main opened outlet. Low water level in well.	Arrest the leakage and close outlet. Lower the pump with reference to well water level
11	More pressure at the entry of sand filter	No bypass in the pipeline/bypass not opened. Displacement of filter element. Less quantity of sand in filters	Provide bypass before filter and regulate pressure. Place filter element properly. Fill required quantity of sand
12.	Accumulation of sand and debris in screen filter	Displacement of filter element. Less quantity of sand in filters	Place filter element properly. Fill required quantity of sand
13.	Ventury not working during chemical treatment and fertigation	Excess pressure on filters Improper fitting of ventury assembly	Bypass extra water to reduce pressure Repair the ventury assembly.
14.	Leakage of water from air release valve.	Damaged air release valve ring.	Replace the damaged ring.

4.8 PROBLEM OF RODENTS AND ANIMALS

Rats and mice are the major rodents in the crop field causing devastating loss in the yield and property in the field. Their bite cuts the tubing of the irrigation lines and causes major problem in irrigation operation. Also, they try to reside at the place of irrigation equipment store, as they dry and warm. They also make burrow holes in the field causing uneven irrigation water distribution. Moreover, they attack the standing crop and if harvested, they trespass to crop storage site. Chemical treatment on the surface of the pipe can be one measure to prevent its damage.

ACTIVITIES

Activity 01: Visit a farm, where a sprinkler irrigation system is installed and perform the following.

Material required

1. Pen
2. Notebook

Procedure

1. Identify the type of sprinkler.
2. Determine the spacing of the sprinkler.
3. Determine the average wetted area of the sprinkler.
4. Prepare a note based on your observations.

Activity 02: Operate the sprinkler irrigation system and perform the following activities.

Material required

1. Pen
2. Notebook

Procedure

1. Determine the average flow rate (discharge) of the system using flow meter.
2. Measure the pressure at the observed discharge using pressure gauge.
3. Prepare a note based on your observations.

Activity 03: Visit a sprinkler irrigation system installed farm site and perform the following activities.

Procedure

1. Inspect for any sprinkler heads missing.
2. Inspect for any sprinkler heads broken.
3. Identify the clogged sprinkler head if any.
4. Determine of coverage by each sprinkler.
5. Measure the operating pressure during operation.

Activity 04: Prepare a maintenance schedule for the sprinkler irrigation system.

Activity 05: Visit a drip irrigation system installed farm site and perform the following activities.

1. Inspect the clogging of any emitter.
2. Perform the flushing operation of the irrigation system.
3. Perform the cleaning of the screen filter

Activity 06: Conduct the backwashing operation of the sand filter installed in the drip irrigation system.

CHECK YOUR PROGRESS

A. Answer the following questions

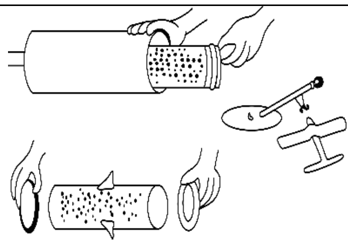
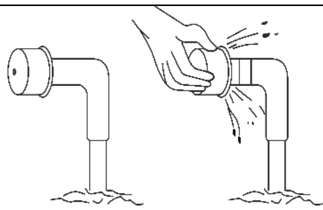
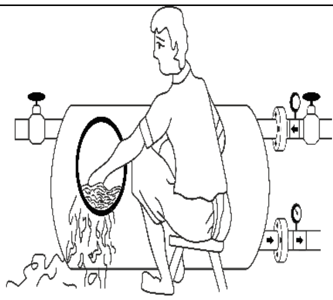
1. Explain the operation of sprinklers.
2. List out some points not to be followed in sprinkler operation.
3. List out the annual maintenance activities to be performed for efficient sprinkler operation.
4. What may be the reasons for not developing enough pressure in the sprinkler irrigation system?
5. List out the daily maintenance activities to be performed for efficient drip operation.
6. Explain acid treatment for irrigation water.

B. Fill in the blanks

1. The key factor for the most efficient irrigation management is the knowledge of …………… and ………………. for the system.
2. Lateral pipes are meant to be checked for ……………….. regularly.
3. Use the …………. type of sprinkler heads throughout the system.
4. Perform routine checks of each sprinkler discharge to monitor the …………… of application.
5. The discharge of system is the ………… of the sprinkler heads or emitters' flow rates.
6. The recommended average pressure difference in the emitters should not be more than …………. percent.

7. …………. is the heart of a drip irrigation system and its failure will lead the poor performance of and in turn.

C. Match the following

Column A	Column B
1. Pressure gauge	 A.
2. Water meter	 B.
3. Flush	 C.
4. Screen filter	D. 
5. Sand filter	 E.

Module 5 Advances in Micro Irrigation Systems

Module Overview

This module delves into advanced concepts and techniques in modern irrigation practices. It explores the evolution and features of advanced micro-irrigation systems, highlighting the benefits of automation in drip and micro-irrigation methods. Learners will gain insights into innovative approaches like soilless cultivation and its various techniques. Additionally, the module discusses sustainable practices such as the use of solar pumps in micro-irrigation systems, offering practical solutions for energy-efficient water management. This module equips learners with cutting-edge knowledge and skills for optimizing irrigation in agriculture.

Learning Outcomes

After completing this module, you will be able to:

- Understand the evolution and key features of advanced micro-irrigation systems.
- Explain the principles and benefits of automating drip and micro-irrigation systems.
- Comprehend the concept of soilless cultivation and its significance in modern agriculture.
- Identify and describe various soilless cultivation techniques.
- Explore advanced irrigation techniques for sustainable agricultural practices.
- Assess the role of solar pumps in micro-irrigation systems for energy-efficient water management.
- Integrate advanced irrigation and cultivation methods into practical agricultural applications.

Module Structure

5.1 Introduction

Due to rapid urbanization and industrialization not only the cultivable land decreasing but also conventional agricultural practices are causing a wide range of negative impacts on the environment. Improvements in the existing methods have taken place for growing sufficient food to sustainably feed the world's growing population. Modification in growth medium could one of the alternatives for sustainable production and to conserve fast-depleting land and available water resources. In the present scenario, automation in the micro-irrigation and adoption of various soil-less cultivation techniques have been successful. These could be considered alternative options for growing healthy food plants, crops, or vegetables. In recent years automated irrigation, soilless cultivation, or hydroponics has come up as a promising strategy for growing different crops. As it is possible to grow short-duration crops like vegetables around the year in very limited spaces with low labour, these advanced cultivation techniques can play a great contribution in areas having limitations of soil and water.

5.2 Evolution and features of advanced micro irrigation system

In recent years many forms of advanced techniques for cultivation have evolved. Starting from switching on or switching off the lights and pumps, many farming operations have become automated. Improvements in such irrigation systems are going on with the integration of various kinds of sensors (like moisture, temperature, etc.) with the control, data processing, and output units. Many of these systems are made operational through wired or wireless networks and sometimes use recent applications of IoT and robotics.

Latest and advanced forms of micro-irrigation such as hydroponics, aeroponics, vertical farming, indoor farming, rooftop farming, and aquaculture, etc. have attracted the attention of farmers from different countries. The concept of plant factories is coming up in countries like Japan, China, Korea, and Indonesia where all these new techniques are being used and refined mainly due to manifold production in limited use of resources. Experts feel that these techniques will be refined and made affordable in the future. These methods not only use minimal input resources like water, land, nutrients/fertilizers, and human efforts but these are successful even in the absence of sunlight and during the off-season. All kinds of nutrition are provided through irrigation. In absence of sunlight, affordable LED lamps provide the light.

5.3 Automation of drip/micro irrigation system

Automation of drip/micro irrigation system refers to the operation of the system with no or minimum manual interventions. Irrigation automation is well justified where a large area to be irrigated is divided into small segments called irrigation blocks and segments irrigated in sequence to match the flow of water available from the water source.

This can be achieved by the use of different kinds of sensors, controllers, data loggers, and displays. Different types of sensors used to monitor soil and plant parameters are as follows:

- Electromagnetic sensors
- Optical and Radiometric sensors
- Mechanical sensors
- Electrochemical sensors
- Acoustic and Pneumatic sensors

Automation commonly eliminates the manual opening and closing of valves. It starts and stops the pump exactly as and when required, thus, optimizing the energy requirement. An irrigation system can be started at any desired time that can be pre-determined or on the basis of actual field measurements. Automation helps to irrigate during the odd time (night). This is especially in Indian conditions, where power supply is available for agricultural operations during night time. Automation helps to change the frequency of irrigation and fertilizer application as per the crop requirement. Use of water from different sources can be made and in turn, we get increased water and fertilizer use efficiency.

5.3.1: Various kinds of automation modes

Automation can be used in a number of ways;

i. To start and stop irrigation through supply channel outlets,
ii. To start and stop the irrigation pumps,
iii. To cut off the flow of water from one irrigation area —either a bay or a section of the channel and direct the water to another area.

Automated micro-irrigation systems are generally of two types – semi-automatic or fully automatic. Most semi-automated systems use mechanical or electronic timers to activate control structures at predetermined times. The irrigator usually determines when to begin irrigation and its duration and manually resets or returns the devices to their original positions or moves them from one location to another before the next irrigation. Fully automatic systems normally operate without the operator's attention except for periodic inspections and routine maintenance. The irrigator may determine when and how long to irrigate and turn water into the system or start programmed controllers to initiate the automated functions. Fully automatic systems may use soil moisture sensors, such as tensiometers or electrical resistance blocks to activate electrical controls when soil water is depleted to predetermined levels. Irrigation duration may be controlled by programmed timers, soil moisture sensors, or surface water sensors. Different types of devices used to monitor soil-plant water status and to automate the irrigation system are listed below:

a) Tensiometer

b) Resistance block

c) Gypsum block

d) Granular matrix sensor

e) TDR-based soil moisture sensor

f) Infrared sensors for leaf air temperature

g) High-frequency capacitance type soil moisture sensor.

The basis of the decision-making of most irrigation operations is either timer-based or volumetric measurement-based, open or closed loop systems, Real-Time feedback systems, or computer-based control systems.

Some sensor and equipements used in automation system

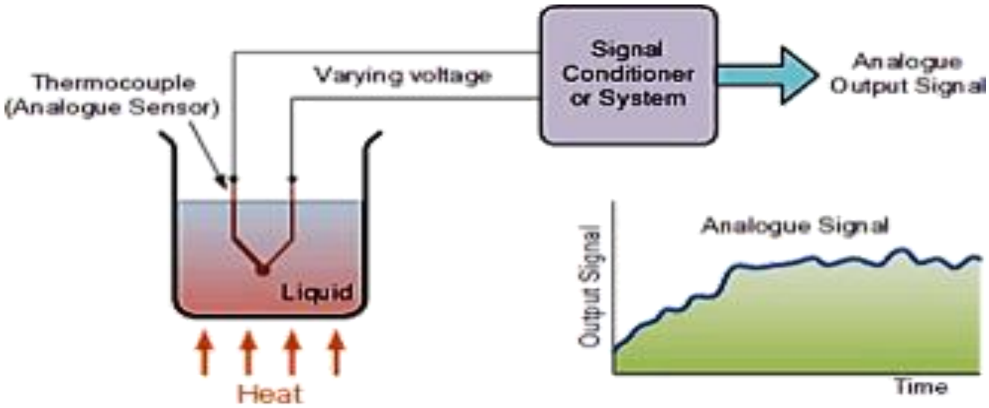


Fig. 5.1: Thermocouple sensor to produce an Analogue Signal

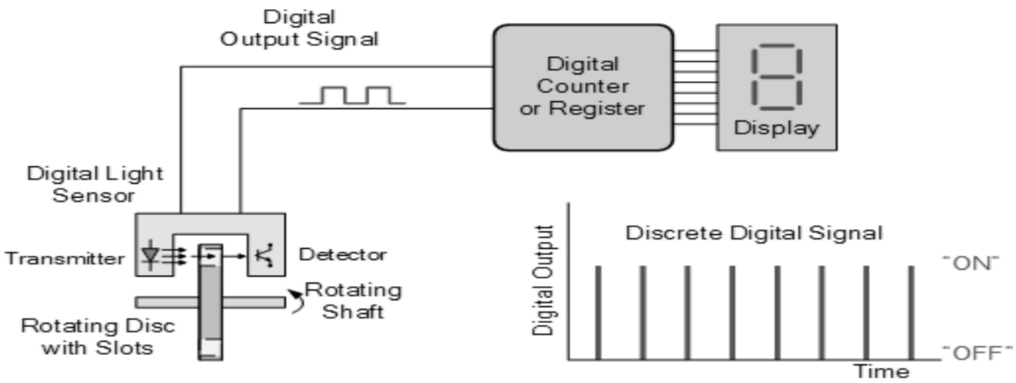


Fig. 5.2: Light Sensor used to produce a Digital Signal

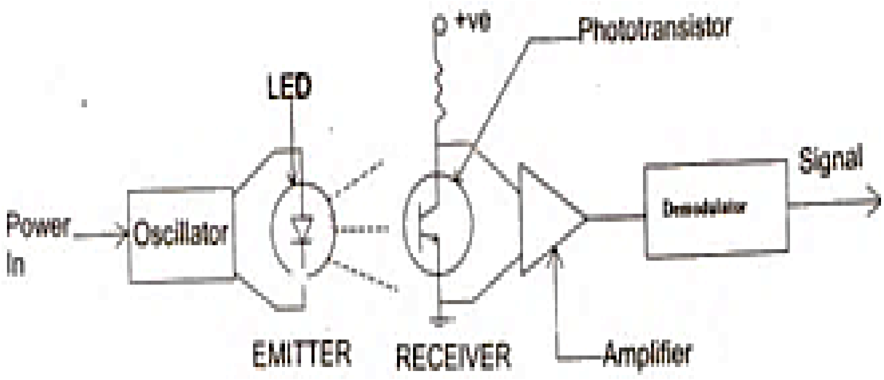


Fig. 5.3: Photoelectric sensor

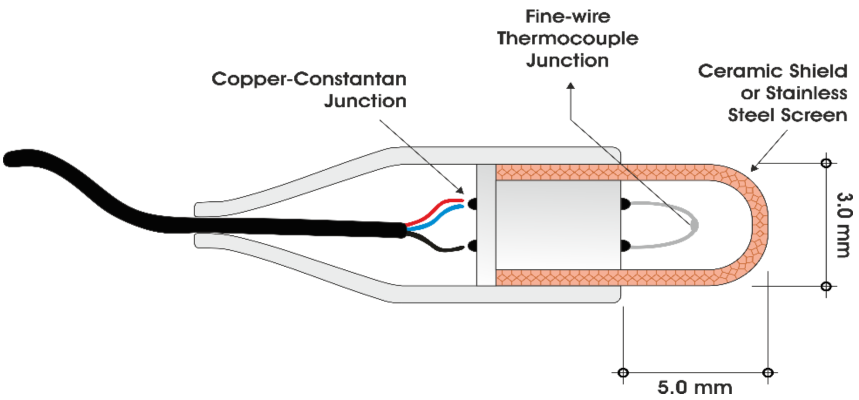


Fig. 5.4: Soil psychrometer

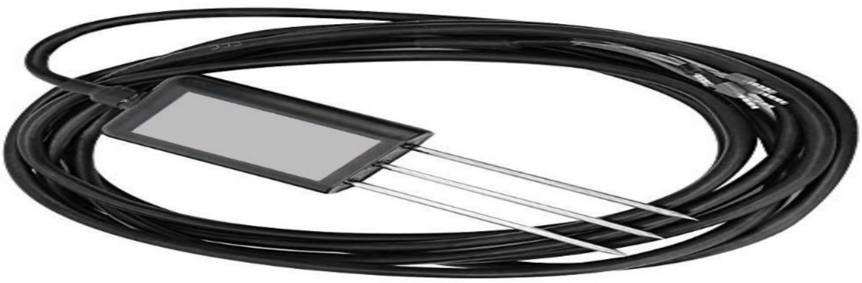


Fig. 5.5: Soil moisture sensor using FDR technology

Fig. 5.6: Gypsum block-based sensor

Fig. 5.7: Torque Sensor features a USB output

Fig. 5.8: Portable Ethernet data logger

5.3.2: Advantages and limitations of automation

The advantages of automatic irrigation systems are:

1. Automated irrigation system requires less manual labour and thereby less drudgery.
2. Crop get irrigation exactly when needed, this enhances yield and increases productivity.
3. Higher flow rates can be effectively managed.
4. Accurate cut-off of water compared to manual checking helps achieve higher water productivity.
5. Minimal loss or reduced runoff of water and nutrients.
6. Overall saving in operational cost.

5.3.3: Limitations of automatic irrigation are:

1. High costs for system/equipment, as well as high installation and maintenance of the equipment/system.
2. High-tech systems may not always be reliable. While setting up an irrigation system installation or some management factors are wrongly fed due to human error causing ill effect on the irrigation system.

3. High maintenance of channels and equipment to ensure it is working properly as well as timely availability of service. The absence of this causes direct loss to the farmers.

5.4: Soil less cultivation

Soilless cultivation can be defined as "any method of growing plants without the use of soil as a rooting medium, in which the inorganic nutrients absorbed by the roots are supplied via irrigation water". The fertilizers containing nutrients to be supplied to the crop are dissolved in the appropriate concentration in the irrigation water and the resultant solution is referred to as a "nutrient solution"

Agriculture without soil includes hydro agriculture (Hydroponics), aqua agriculture (Aquaponics), and aerobic agriculture (Aeroponics) as well as substrate culture. Among these hydroponics, techniques are gaining popularity because of their efficient management of resources and food production. The growing environment could be generally free from pests and disease. Various commercial and specialty crops can be grown using hydroponics including leafy vegetables, tomatoes, cucumbers, peppers, strawberries, and many more.

5.5: Irrigation techniques

Two kinds of basic irrigation techniques are practiced in soilless cultivation. Open systems, where the water and nutrients are supplied as in conventional soil culture and the surplus (about 25%) nutrients and water is allowed to run to waste. Whereas in Closed systems, the water and nutrient solution is circulated for its reuse and hence no wastage occurs.

Water-nutrient solutions are applied through traditional drippers, foggers, micro-tubes (sphagatti), wicks through the subsurface application. Plant roots are exposed to solutions directly either through direct or intermittently dipping with or without plant supports.

5.6: Kinds of soilless cultivation techniques

Soilless cultivation is usually classified according to the type of plant support as substrate culture (artificial, mineral or organic growing media, or a mixture of these); water culture or hydroponic, where roots are partially or completely dipped in the nutrient solution and aeroponics, where plant roots are suspended in the air beneath and nutrient solution is sprayed in fine mist form to the roots of plants.

For a successful soilless system optimum plant-grown environment in terms of water, air, and anchorage for roots, all necessary nutrients at optimum pH and EC are required. Also the temperature of the root and shoot zone and optimum light is of utmost importance. Therefore, an appropriate mechanism for monitoring and control of these parameters is provided by manual or automatic means.

1. Hydroponics

Soilless cultivation and hydroponics are sometimes used interchangeably. We can define hydroponics as the science of raising crops without the use of soil but with or without the use of inert mediums like sand, peat, gravels, coco coir, pumice, rice husk, or other materials called substrates. Generally, hydroponics allows growers to grow plants in a more efficient and productive manner with less labor and time required. The science of hydroponics/soilless cultivation proves that soil isn't required for plant growth but the elements, minerals, and nutrients that soil contains are provided by a water solution that is rich in macronutrients like nitrogen, potassium, phosphorus, calcium nitrate, and micronutrients like manganese, zinc, etc. The nutrients used in hydroponic systems may come from different sources, including fish excrement, duck manure, purchased chemical fertilizers, or readymade artificial nutrient solutions.

Types of hydroponics

1. **Wick System:** The simplest type of hydroponic system is the wick system (Fig. 5.9). This type of system has no moving parts. It works by wicking up the liquid (water and nutrient) like an oil lamp. It can be constructed in many ways and out of many materials. The plant is placed in the growing medium, and the growing medium is kept moist from the wick. The wick is simply made from a strip of a highly absorbent material like felt or cotton. The wick spreads through the growing medium with one end at the bottom of the container having the nutrient. As the plants utilize the moisture in the growing medium, the wick continually sucks up moisture, keeping the growing medium moist with the nutrient solution.

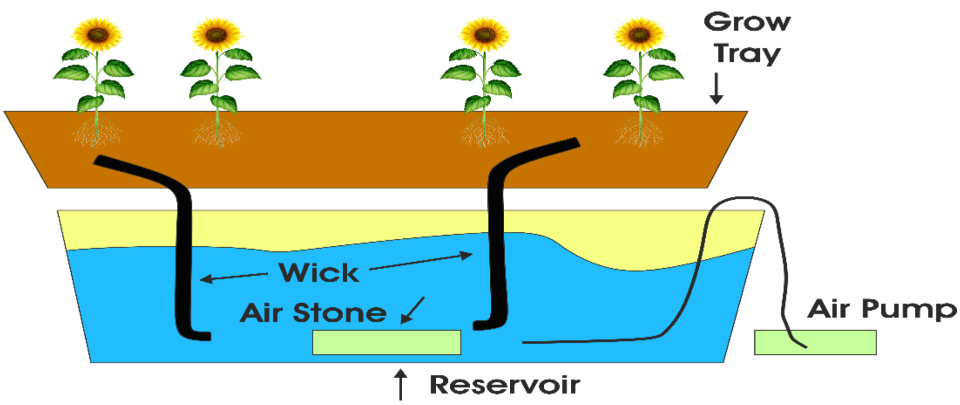


Fig. 5.9: Wick system

2. **Water Culture System:** The water culture system is a simple type of hydroponic system and is sometimes called as bubbleponics (Fig. 5.10). The plant roots are suspended/floating usually on Styrofoam rafts with holes cut (because it floats on

top of the water) directly in the nutrient reservoir in this system. The plants remain in contact with water nutrient solution that has a continuous flow of tiny air bubbles to the root systems through an air pump (and air stones). The roots get the air/oxygen they need and plants do not suffocate from being completely submerged all the time. With this method, the plants grow much faster because of the high amount of oxygen that the roots receive.

Two kinds of deep-water culture are practiced. While in a standard deep-water method, the plant roots hang into a nutrient solution reservoir, in the top-fed deep water culture technique highly oxygenated nutrient solution is delivered direct to the root zone of plants from a separate re-circulating tank. The biggest advantage of top-fed deep-water culture over standard deep water culture is increased growth during the first few weeks.

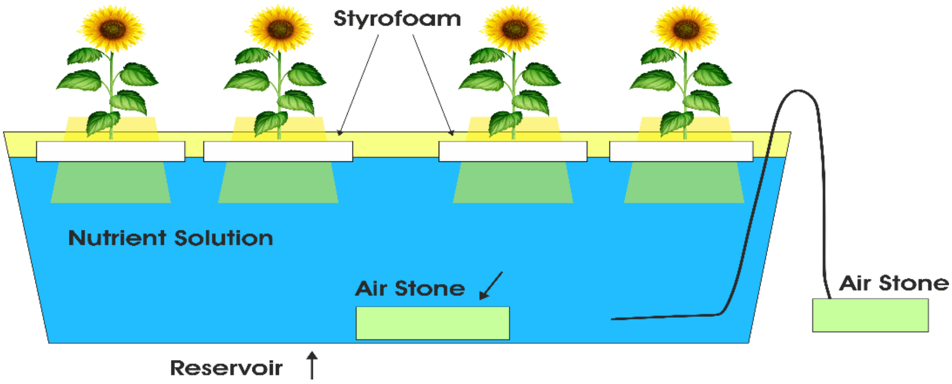


Fig. 5.10: Water culture system

3. **Ebb & Flow (Flood & Drain) System:** In the Ebb and Flow system (Fig. 5.11), a tray is filled with growing medium (clay granules being the most common) for the plants. The tray is placed above a nutrient solution tank/reservoir so that the siphoning action will automatically drain the nutrient solution when the pump is not running. The timer is used to periodically flood the system to keep the roots moist. The second part of the Flood and Drain system is where the plants are contained. This is often constructed in any number of ways, but always has two main parts to it. First is the fill line, which is connected to the pump and fills the system when it's turned on. Second is the overflow tube, which is set at a particular height, usually about 2 inches below the top of the growing medium. This keeps the water level in the system from overflowing out of the containers the plants are in, and instead, it flows directly back into the reservoir to be pumped back up to the plants again.

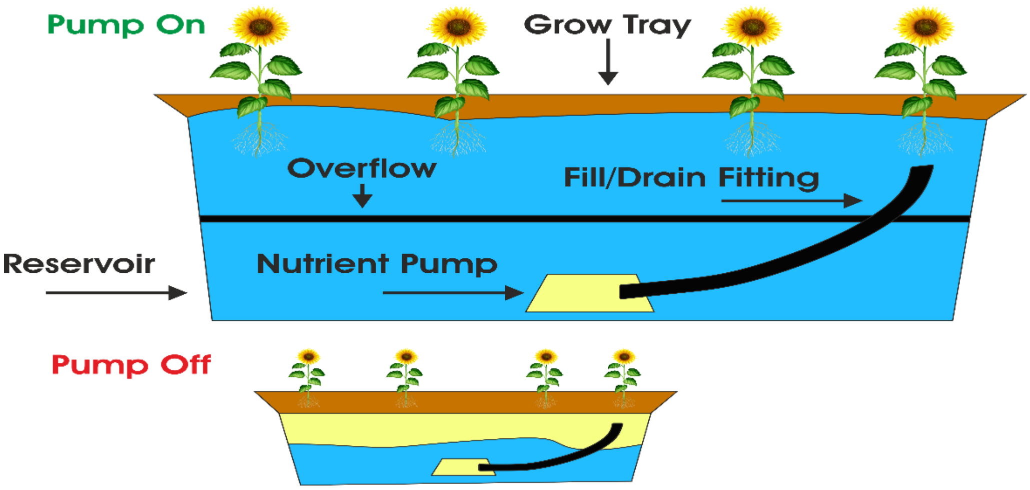


Fig. 5.11: Ebb and flow system

4. Nutrient Film Technique (NFT System): A thin film of nutrient solution flows through closed channels or pipes in which plants are placed. The NFT system is popular and quite similar to the Ebb and Flow except for a few things. Nutrient solution circulates by a water pump without time control throughout the entire system; travels through the growth tray and circulates back to the reservoir through gravity below the level of the plants. The flow rate of solution is generally 2-3 liters per minute for a balcony-based system.

The main difference between the two is that an NFT system does not actually flood the system. The roots that reach down into the nutrient solution, are able to supply moisture to the upper roots, and the upper roots can also still get the air/oxygen that the plants need as well. Construction of an NFT system could be made in many different ways, they are usually laid out as series of slightly slanted tubes in rows that hold the plants. The tubes allow the water to be directed easily from one end of the tube to the other end, that way all the roots receive water (nutrient solution).

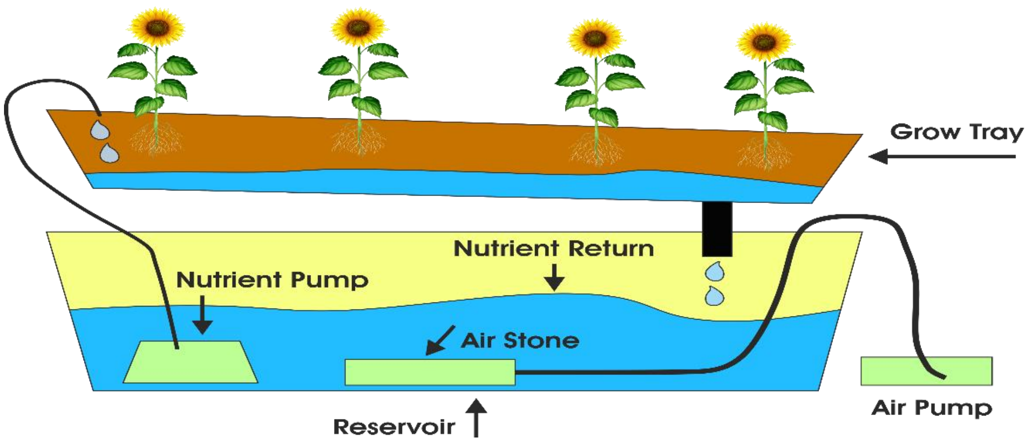


Fig. 5.12: Plants in nutrient film technique

5. Drip systems: Drip systems are similar to drip irrigation systems used for fields. Instead of plain water, the aerated nutrient solution (just like any other hydroponic system) is applied in hydroponic drip systems generally having plants on the substrates. There are actually two ways to run a drip system, a recovery system (closed), or a non-recovery system (open). A recovery system means that you collect the nutrient solution after application and return it back to the reservoir, where it can be pumped out to the plants again. In a non-recovery system, the solution is not recirculated and either wasted or applied in the open field to utilize some nutrients.

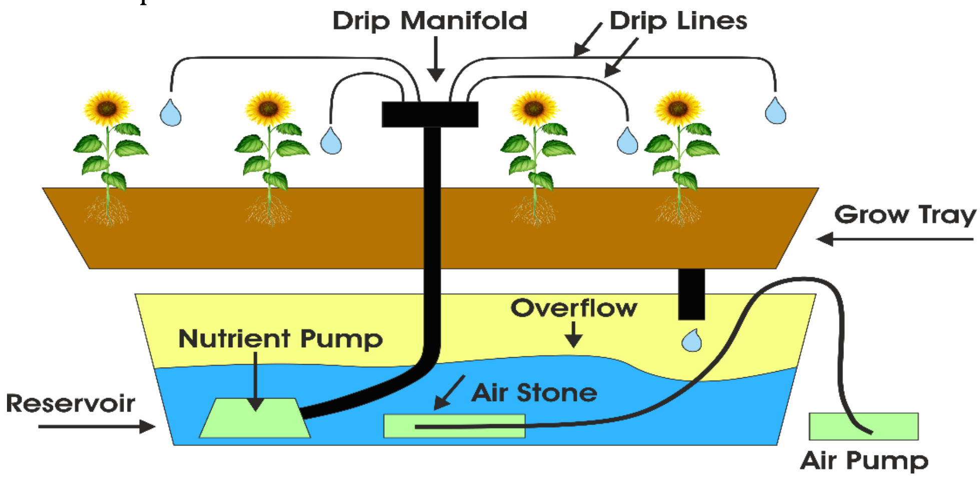


Fig. 5.13: Drip irrigation technique

Advantages and disadvantages of hydroponic systems

Several advantages, as well as limitations, can be listed for hydroponics systems.

Advantages:

1. Like in greenhouses, hydroponic growers can have total control over the climate - temperature, humidity, light intensification, and the composition of the air. In this sense, you can grow foods all year round regardless of the season.
2. No soils are required to grow plants.
3. Make better use of space and location, you can grow your plants much closer, and consequently huge space savings.
4. Farmers can produce foods at the appropriate time to maximize their business profits.
5. Hydroponics is a huge water-saving method, water is recirculated and plants grown hydroponically can use only 10% of water compared to field-grown ones.
6. In Hydroponics, we have 100% control of the nutrients (foods) that plants need. Nutrients are conserved in the tank, so there are no losses or changes of nutrients like they are in the soil.
7. Since, all of minerals are contained in the water solution. You can measure and adjust its pH levels more easily as compared to the soils.
8. As the plants are placed in ideal growing conditions, plants no longer waste valuable energy searching for diluted nutrients as in soil, and huge yields and growth are obtained.

9. Weeds are mostly associated with the soil in no soil conditions hydroponics is weeds free and we get rid of efforts and money to remove weeds.
10. Plants are less vulnerable to soil-borne pests like birds, gophers, and groundhogs; and diseases like Fusarium, Pythium, and Rhizoctonia species. When growing indoors it has more control of most surrounding variables in hydroponics.
11. No or very limited chemicals are used in hydroponics for insecticides and herbicides. This helps to grow cleaner and healthier foods.
12. Besides spending less work on tilling, watering, cultivating, and fumigating weeds and pests, you enjoy much time saved because plants' growth is proven to be higher in Hydroponics. So, it is a time and labour saving system.

Disadvantages and Challenges:

1. Mother nature and soils help regulate crops even if something goes difficult or the growth environment is not favorable. That's not the case in Hydroponics. A Hydroponic Garden requires your valuable time and commitment. Plants die out more quickly without proper care and adequate knowledge.
2. Involving many types of equipment, which requires necessary specific expertise for the devices used, a high level of experience, skills, and technical knowledge is required.
3. You are running a system of what plants you can grow and how they can survive and thrive in a soilless environment. Mistakes in setting up the systems and plants' growth ability in this soilless environment end up ruining your whole progress.
4. A hydroponic system runs on water and electricity. Besides the availability of a continuous supply of electricity and water, a high risk involved due to the close proximity of various equipment, safety in the working environment should be the priority.
5. There is a threat due to total dependence on electricity to manage the whole system. So suppose you do not take preliminary actions for a power outage, the system will stop working immediately, and plants may dry out quickly and will die in several hours. Hence, a backup power source and plan should always be considered, especially for large-scale commercial systems.
6. Hydroponics systems are very expensive and rare. The cost of containers, lights, pumps, timer, growing media, nutrients solution, etc together adds up besides operational costs and electricity.
7. It takes longer to get returns for the investments made in hydroponics.
8. Diseases and pests may spread quickly in these systems. Mainly due to plants that grow in close proximity and use the same water. Small infections or pests on crops may escalate fast. You should have a good disease management plan.

2. Aeroponics

The basic principle of aeroponic growing is to grow plants suspended in a closed or semi-closed environment by spraying the plant's dangling roots and lower stem with an atomized or sprayed, nutrient-rich water solution. The leaves and crown, often called the canopy, extend outside. The roots of the plant are separated by the plant support structure. Therefore, the nutrient solution is sprayed frequently on the roots by misters/nozzles. The system is normally turned on for only a few seconds every 2-3 minutes. This is sufficient to keep roots moist and the nutrient solution aerated. It also inhibits algal growth due to darkness. Excess nutrient solution drips down off the roots into a reservoir or collection area re-sprayed. Often, closed-cell foam is compressed around the lower stem and inserted into an opening in the aeroponics chamber, which decreases labor and expense; for larger plants, trellising is used to suspend the weight of vegetation and fruit. Aeroponics systems can be sometimes combined with NFT or other hydroponics systems that help during breakdowns of the main system as an alternative. These systems generally provide the highest water productivity.

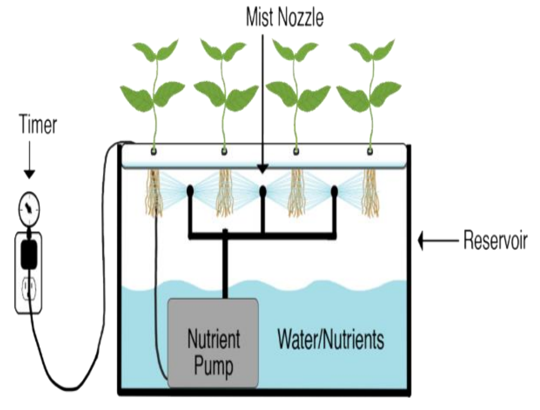


Fig. 5.14: Aeroponics irrigation technique

Fig. 5.15: Aeroponics for potato seed production

Major Components of an aeroponics system include a reservoir, pump, misting nozzles/jets, tubing to distribute water, baskets to hold and suspend plants, and an enclosed growing chamber for the roots. A storage reservoir can be made up of various materials to store the re-circulated nutrient solution. A matching pump with a timer circuit is fitted with proper tubings to generate the rated pressure of the nozzles.

Advantages and disadvantages of aeroponic systems

Several advantages and disadvantages are worth considering for the aeroponics approach.

Advantages of Aeroponics

1. Possible to operate at three different pressure ratings like high, medium, and low are possible with modern aeroponics.
2. Healthier root systems allow a massive amount of plant growth and yield.
3. Old plants can easily be replaced with new ones.

4. Most suitable for high-maintenance crops, herbs and
5. Less maintenance is required.
6. It requires very little space to create high levels of production.
7. You have more mobility available when using aeroponics.
8. It takes fewer resources to produce a yield through aeroponics.
9. Aeroponics provides us with a valuable research tool.
10. You can take clones from your best plants to increase production levels.
11. The power requirements for growth are significantly less.

Disadvantages of Aeroponics

1. Aeroponics facilities require constant monitoring to be successful.
2. It is an expensive method and requires a high initial investment.
3. Aeroponics is highly susceptible to power outages.
4. High levels of skills are required to operate aeroponics, technical knowledge is pre-requisite.
5. Aeroponics require regular disinfection of the root chamber.
6. The equipment relies heavily on automatic systems.
7. Aeroponics systems is sometimes noisy in an enclosed environment.

Substrate/Media for soilless/hydroponic cultivation

Soilless cultivation can be practiced with or without media that support the plant and its root system, besides holding and making available the water and nutrients. These are made of either organic or inorganic or artificially made synthetic materials. Here are some media which are generally used in soilless cultivation to support roots and maintain a good water/oxygen ratio.

- **i.** **Coco Peat / Coco Coir:** Most of the hydroponic growers prefer Coco coir which is made from ground-up coconut husks that act as a great medium for plants having a good air-to-water ratio. The coco peat is organic, compactable, and sustainable.
- **ii.** **Expanded Clay Pellets:** These are made of clay in the form of round balls having a porous constitution. They release almost no nutrients into the water stream and are pH neutral and reusable. Their spherical shape and porousness help to ensure a good oxygen/water balance. But these are heavy and dry out fast.
- **iii.** **Perlite:** Perlite is a soil-free growing medium that helps to add aeration to soil mixes. It is created by the air-puffing volcanic glass as an extremely light and porous material. It has one of the best oxygen retention levels of all growing media. Perlite is generally mixed with coco coir, soil, or vermiculite. It has potential danger when inhaled.
- **iv.** **Vermiculite:** Vermiculite is similar to Perlite. It is a mineral that is heated until it expands into pebbles. It retains more water than perlite and can wick (draw) water

and nutrients upwards. This is commonly used in combination with other types of media to create highly customized media for specific hydroponic applications. Yet it is a little expensive in comparison to other substrates and can hold too much water which may not be good for some plants.

v. **Nursery blocks:** Nursery blocks are made up of organic compost and don't break apart like soil due to a biodegradable binding material. These blocks are placed in trays and the roots grow straight down towards the opening in the tray at the bottom. So it is good for nursery raising. This is helpful when transplanting into any type of hydroponic system, where roots growing out to the sides aren't as beneficial.

vi. **Rockwool:** Rockwool is made by melting rock and spinning it into extremely thin and long fibers, similar to fiberglass. They take these fibers and press them into cubes of varying sizes. Rockwool has all of the benefits of most growing media, with some pretty serious downsides. It's not easy to dispose of – thin fibers of melted rock will last essentially forever when disposed of. Additionally, they usually come at a high pH and need soaking.

			
Fig. 5.16: Coco Peat / Coco Coir	**Fig. 5.17: Expanded Clay Pellets**	**Fig. 5.18: Perlite**	**Fig. 5.19: Vermiculite**
			
Fig. 5.20: Nursery blocks	**Fig. 5.21: Rockwool**	**Fig. 5.22: Rice Husk**	**Fig. 5.23: Sand**
			

Fig. 5.24: Gravels	Fig. 5.25: Wood Fiber	Fig. 5.26: Brick Shards	Fig. 5.27: Saw dust
			
Fig. 5.28: Polysterene	Fig. 5.29: Sheep wool	Fig. 5.30: Growstones	Fig. 5.31: Hydrogel

vii. **Rice Husk:** These are the shells that surround rice. These are organic materials and we utilize them as a byproduct that otherwise gets wasted. They allow for good drainage and retain little water in general. But it decays over time and sometimes doesn't meet the water requirement of the crop.

viii. **Sand:** Sand is one of the most plentiful and inexpensive types of media that is easily available. It is heavy at the same time it has low water retention. Due to the small grain size may not be suitable for certain hydroponic systems

ix. **Gravels:** Gravels are crushed stones. These can be used in some hydroponic systems. These are very inexpensive, easy to clean as well as easily drainable. But heavier in weight as well as poor in water holding, which makes it unsuitable for certain hydroponic systems as the plant roots may dry out quickly.

x. **Wood Fiber:** Wood fibers are usually cellulosic elements that are extracted from trees and used to make materials including paper. As a substrate in hydroponics, wood wool (i.e. wood slivers) could be a substrate of choice since the earliest days of hydroponics research. However, more recent research suggests that wood fiber can have detrimental effects on "plant growth regulators". These are biodegradable but not sterile and attract pests.

xi. **Brick Shards:** These are crushed-up bricks and are similar in effect to gravel. However, they may affect the pH as they are not pH neutral, and also require extra cleaning to get rid of brick dust. Crushed bricks along with other components are generally used for growing orchids. These are inexpensive but heavy and hold less water.

xii. **Sawdust:** Sawdust or wood dust is a by-product or waste product of woodworking operations such as sawing, milling, planning, routing, drilling, and sanding. It is composed of fine particles of wood. Sawdust is also used as media in hydroponics. It is inexpensive, biodegradable, and has similar properties to wood fiber.

3. Aquaponics

It is the combination of growing plants hydroponically and the practice of aquaculture (raising fish). Similar to hydroponics, plants in an aquaponics system grow in a soilless environment. Fish are grown simultaneously in the aquatic environment which provides a symbiotic relationship and results in an incredibly efficient system. Fishes provide a natural source of organic nutrients through their excreted waste, beneficial microbes convert the waste into usable nutrient sources for the plants. Plants in turn filter the water and provide a clean living environment for the fish as well as the microbes. In aquaponics, the microbes convert the ammonia from the fish waste into nitrites and then into nitrates. Plants then take in the nitrates through their roots using them as a source of plant essential nitrogen. The combination of hydroponics and aquaculture allows aquaponics to draw upon the benefits of both systems while minimizing the individual drawbacks of each.

4. Vertical farming

This is a system of farming in which more than one layer of crops is raised in a vertical fashion involving large-scale production. It is an intensive farming strategy that mainly employs advanced techniques such as soilless cultivation, hydroponics, and aeroponics to produce crops like fruits, vegetables, and edible mushrooms continuously throughout the year.

5. Indoor farming

This is a method of growing generally leafy vegetables, inside climate-controlled warehouses or buildings using vertical farming and hydroponic techniques. Indoor farming may include other components also like dairy, poultry, aquaculture etc.

5.7: Solar pump in micro irrigation systems

Over 65 percent of the irrigated area in India is covered by groundwater sources, i.e. water is pulled up and distributed via various kinds of irrigation pump sets. Prior to the availability of solar pumps, these were either powered by diesel or via grid-connected electrical pumps. The pumps themselves can be submersible pumps and surface pumps (mostly horizontal centrifugal pumps), which are either direct current (DC) pumps or alternate current (AC) pumps.

Surface pumps: The surface pumps are installed and remain dry out of the water and in the open. They are installed where the water table is within a depth (or head) of up to 6.5 meters which is within the practical limit of suction height. As they need to be on the surface, these pumps are easier to install and maintain.

Submersible pumps: As the name suggests, a submersible pump is installed deep below the ground level and remains submerged underwater. These are generally found in tubewells where the suction head is beyond a depth (or head) of 6-7 meters (Theoretically up to 10 meters). The installation of these pumps is done by digging a borewell.

DC pump: This pump runs on a motor that operates on direct current, therefore no battery or inverter is needed in this type of pump, and can be connected to the DC solar output.

AC pump: The motor of this pump operates on alternating current, which means the direct current produced by the solar panels gets converted to AC using the inverter. The conversion from DC to AC leads to a loss of power from generation and consumption.

A photovoltaic cell converts the Sun's energy falling on its surface in the form of solar radiation into electricity. A solar photovoltaic array consists of several photovoltaic cells. A typical solar pump runs on a photovoltaic array of cells also called a PV system. This PV array is installed on a frame such that it faces the Sun for a maximum period during the whole year. The PV array provides a DC supply to a connected pumping system. The simplest PV water-pumping systems consist of just a PV array attached to a DC pump. There could be an inverter that converts DC to AC for a common kind of AC motor. The motor and pump are generally monoblock surface or submersible as described above. A pump pulls the water from a well or spring and that can be stored in either a pressurized or an unpressurized overhead tank. The Water storage tank is the equivalent of a battery - to time shift supply when demand is necessary. This means that the storage helps to supply the water at odd hours during restricted availability of solar radiations. The pump (or tank) may also be connected to a drip irrigation system to efficiently disburse the water.

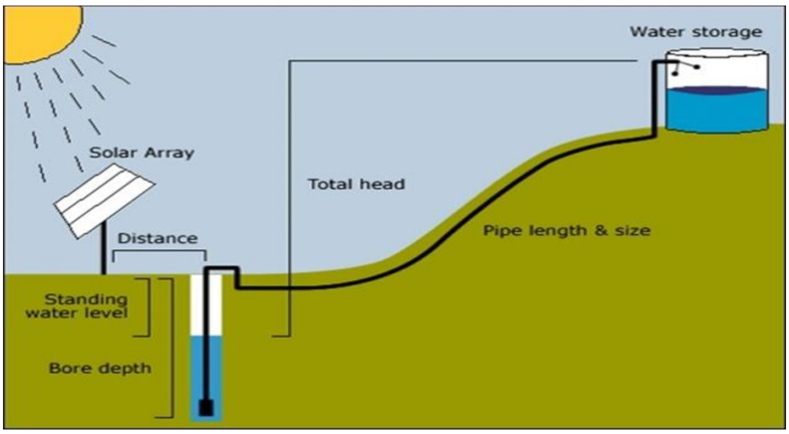


Fig. 5.32: Solar Irrigation

The incoming solar radiations start reaching Earth's surface with the advent of daylight and stop during the night. But the peak of radiation is at noon time when the Sun is vertically above the ground surface. So, to deal with this a device known as a solar trekker is sometimes installed on the PV units that keep tracking the direction of the Sun. Thus an increased voltage and total energy output are obtained.

Advantages and limitations

There are many advantages listed as following

- Solar irrigation can help to increase farmers' incomes, particularly for remote producers with inconsistent access to electricity or fuel.
- Pump irrigation reduces labor for water delivery.
- By targeting water at a crop's roots, micro-irrigation can reduce the weed and disease pressures, and increase the efficiency of chemical applications.
- Drip irrigation significantly increases water use efficiency.
- It makes irrigation possible in remote areas.
- Solar pump-based micro-irrigation systems are environmentally friendly.
- These have minimal operating costs mainly due to reduced electricity bills.
- It does not require extra fuel or energy and required minimal minimal maintenance.

Following limitations of solar micro-irrigation system are listed below

- Solar pump-based micro-irrigation systems are one of the costliest prepositions.
- It does not attract farmers' attention for investment, mainly due to the policy of free electricity.
- It runs best during noon when the maximum radiations are available, which time period is generally not suitable or recommended for irrigating the crops under micro-irrigation.
- Being a newer technology, the repair, and service maintenance facilities are not widely and easily available.
- The adoption and use of micro-irrigation have been to a few limited crops although it can be expanded.

ACTIVITIES

Activity 01: Visit the agriculture farm to see the automation system.

Material required

1. Notebook
2. Pen

Procedure

1. First take permission from the agriculture farm owner.
2. Visit the agriculture farm.
3. Identify the automation system that is installed.
4. Then, list the name of the components of the automation system.
5. Draw a sketch of the automation system.

Activity 02: Draw the line diagram of the Soil psychrometer sensor.

Material required

1. Notebook
2. Pencil
3. Eraser

Procedure

1. Identify the soil psychrometer sensor.
2. Draw the figure of the soil psychrometer sensor.
3. Label the parts of the soil psychrometer sensor.

Activity 03: Draw the line diagram of the water culture system.

Material required

1. Notebook
2. Pencil
3. Eraser

Procedure

1. Identify the water culture system.
2. Draw the figure of the water culture system.
3. Label the parts of the water culture system.

CHECK YOUR PROGRESS

A. Answer the following question

1. Define hydroponics and write their types.
2. What do you mean by soilless cultivation?
3. Explain aeroponics and how it will work?
4. Write the name of the media required in a hydroponics system.
5. Differentiate between vertical farming and indoor farming.
6. Explain the term aquaponics.
7. Describe the role of solar pumps in irrigation systems?

B. Fill in the blank

1. Automation of drip/micro irrigation system refers to the operation of the system with no or minimum …………… interventions.
2. An irrigation system can be started at any desired time that can be ……………………… or on the basis of actual field measurements.
3. Automated irrigation system requires ………………….. manual labour and thereby less drudgery,
4. Crop get irrigation exactly when needed, this enhances yield and …………………productivity.
5. Higher …………… rates can be effectively managed.
6. Accurate ………….. of water compared to manual checking helps achieve higher water productivity.
7. …………… loss or reduced runoff of water and nutrients.
8. Perlite is a ………… growing medium that helps to add aeration to soil mixes.
9. Wood fibers are usually …………………… elements that are extracted from trees and used to make materials including paper.
10. Water-nutrient ………… are applied through traditional drippers, foggers, micro-tubes (sphagatti), wicks through the subsurface application.

C. Match the following

Column A	Column B
1. Perlite	A. 
2. Sand	B. 
3. Brick Shards	C. 
4. Wood Fiber	D. 

5. Sheep wool	E. 
6. Nursery blocks	F. 
7. Growstones	G. 

Glossary

Agriculture	The art and science of cultivating crops and rearing domestic animals.
Automation	It is a term for technology applications where human input is minimized.
Back flush	The process of flowing pressurized water backward through a filter to remove trapped debris and restore the filtration system for ongoing use.
Back pressure	An increase of pressure in the downstream piping system above the supply pressure at a point of consideration, which can cause a reversal of the normal direction of flow.
Clogging	It is the blocking of drip emitters by silt or other suspended solid matter.
Consumptive use	Consumptive use refers to the amount of water utilised for a beneficial purpose that does not return to the groundwater or surface water source, such as water transpired by growing vegetation, evaporated from soils or water surfaces or integrated into goods.
Contour lines	A contour line is an imaginary line that is obtained by joining the points of constant elevation on the surface of the ground.
Contour map	A topographic map on which the shape of the land surface is shown by contour lines, the relative spacing of the lines indicating the relative slope of the surface.
Drip lateral	A water delivery pipeline or Low Linear Density Polyethylene (LLDPE) pipe that supplies water to the emitters from the main lines or sub-mains.
Emitter	An irrigation device moulded from plastic and designed to deliver precise amounts of water to particular areas.
Evaporation	The transformation of water from a liquid to a gas or vapour is known as evaporation.
Evapotranspiration	Evapotranspiration (ET) is the sum of water evaporation and transpiration from a surface area to the atmosphere. The flow of water to the air from sources like soil, canopy interception, and water bodies is accounted for by evaporation.
Fertigation	The application of fertilizers, plant nutrients or amendments through an irrigation system.
Fertilizer	An organic or inorganic material, either natural or synthetic, used to supply elements, such as nitrogen, phosphate, potash, etc., which is essential for plant growth.
Flow rate	The rate of flow or volume per unit period of time.

Flushing	It involves opening the ends of a pipe system and using an appropriate velocity to flush sediment and algae built up in sub-mains or tubes.
Groundwater	It is the water below the Earth's surface. Water stored in an aquifer is also called groundwater.
Horsepower	The power of an engine is measured in terms of horsepower (about 745.7 watts).
Infiltration	The process of water movement through the soil surface into the soil matrix.
Infiltration rate	The velocity or speed at which water permeates into the soil. It is, usually, measured by the depth (in mm) of water layer that enters the soil in one hour.
Irrigation	It is the technique of applying controlled amounts of water to land in order to aid agricultural production.
Irrigation frequency	It is the measure of the number of irrigations applied per unit of time.
Irrigation interval	The average interval between the commencement of successive irrigations in a field or an area.
Irrigation schedule	The schedule that decides when to irrigate a land and how much water to apply as per the measurement or estimate of soil moisture or crop water used by a plant.
Irrigation system	It includes the water source, water distribution network, control components and irrigation equipment.
Laterals or lateral pipes	Pipes used for conveying water from sub-main lines in case of drip irrigation, while in sprinkler irrigation, sprinklers are mounted on these pipes.
Micro irrigation	An irrigation system with small, closely spaced outlets used to apply small amounts of water at low pressure.
pH	Negative logarithms of H+ ion concentration of a given solution.
Pressure gauge	A device used for measuring the pressure of water.
Pressurized irrigation	An irrigation system, in which water is conveyed to and distributed over farmland through a network of pressurized pipes.
Pump	A device that discharges a fluid by increasing the pressure.
Root zone	The depth of soil up to which the plant roots readily penetrate, and in which predominant root activity takes place.
Run-off	It is the downward movement of rainwater or surface water under gravity in channels ranging from small rills to large rivers.
Screen filter	A filter utilizing fine mesh screens to remove particles from flowing water.

Surface irrigation	The application of water on land by surface flow.
Surface soil	The upper part of the soil mass about 10–20 cm in thickness.
Surface water	It refers to an open water body like river, stream or lake.
Sustainable agriculture	A systematic approach to agriculture that focuses on ensuring long-term productivity through the use of natural resources for meeting food and fiber needs.
Topography	The study of the shape and features of land surfaces. It refers to the slope of the ground and how much uneven or levelled it is.
Topographic map	A map that contains information about the topography of an area.
Transpiration	Water movement through a plant and evaporation from aerial portions such as leaves, stems, and flowers is known as transpiration.
Water holding capacity	It is the amount of water that a given soil can hold for crop use.

Answer Key

S.No.	Fill in the blank	Match the following
Unit 01	1. moisture content 2. desired 3. radioactive 4. conductivity 5. successive 6. when and how	1. D 2. C 3. A 4. B
Unit 02	1. planning and design 2. Contour 3. water source 4. stage and season 5. Discharge 6. Computation 7. Decreases 8. Turbulence 9. Low 10. Function 11. infiltration	
Unit 03	1. cost 2. nutrients 3. protein 4. nutrient 5. salt index 6. process	1. C 2. A 3. D 4. F 5. B 6. E
Unit 04	1. operation and maintenance 2. maintenance 3. same 4. uniformity 5. Sum 6. 20 7. Filter	1.E 2.D 3.B 4.A 5. C
Unit 05	1. manual 2. pre-determined 3. less 4. increases 5. flow 6. cut-off 7. Minimal 8. soil-free 9. Cellulosic 10. solutions	1. C 2. G 3. A 4. E 5. F 6. D 7. B