

**Practical Manual**  
**M. Sc. (Agri.) Agronomy**  
**Principles and Practices of Water Management**  
**Course Code - AGRO 0504**  
**Course Credit - 3(2+1)**  
**Semester: 2nd**



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*Shaping Lives...  
Empowering Communities...*

**Department of Agronomy and Agroforestry**  
**M. S. Swaminathan School of Agriculture**  
**Centurion University of Technology and Management, Paralakhemundi**  
**[www.cutm.ac.in](http://www.cutm.ac.in)**

**August, 2022**

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*Certificate*

*Certified that this is a bonafide record of practical work done*

*by Mr./ Ms. \_\_\_\_\_*

*Regd. No. \_\_\_\_\_ in M. Sc. (Agri.) programme, Course No.  
AGRO 0504 entitled “principle and practices of water management” during 2nd  
semester of the academic year 2022-24.*

**Date:**

**Faculty In charge**

**Evaluation System**  
**PRINCIPLES AND PRACTICES OF WATER**  
**MANAGEMENT COURSE CODE – AGRO 0504**

<b>Sl. No.</b>	<b>Marks distribution*</b>	<b>Total marks (25)</b>	<b>Marks obtained</b>
<b>1</b>	<b>Record</b>	<b>5</b>	
<b>2</b>	<b>Attendance</b>	<b>5</b>	
<b>3</b>	<b>Lab work</b>	<b>15</b>	
<b>Total (25 marks)</b>			

**Signature of Faculty In-charge**

## List of Experiments

Exp. No.	Date of Exp.	Title	Page No.	Signature	Remark
1		Determination of Field capacity by field method			
2		Determination of infiltration rate by double ring infiltrometer			
3		Determination of Permanent Wilting Point by sunflower pot culture technique			
4		Determination of Field capacity and Permanent Wilting Point by Pressure Plate Apparatus and Hygroscopic Coefficient			
5		Determination of maximum water holding capacity of soil			
6		Measurement of matric potential using gauge and mercury type tensiometer			
7		Determination of soil-moisture characteristics curves			
8		Determination of saturated hydraulic conductivity by constant and falling head method			
9		Determination of hydraulic conductivity of saturated soil below the water table by auger hole method			
10		Determination of effective rainfall (calculations)			
11		Determination of irrigation requirement of crops (calculations)			
12		Determination of ET of crops by soil moisture depletion method and Determination of water requirements of crops (calculations)			
13		Measurement of irrigation water by volume and velocity-area method and measurement			
14		Calculation of irrigation efficiency			

## Experiment No. 1

Date-----

### Determination of Field capacity by field method

Field capacity is the moisture content in percentage of a soil on oven dry basis when it has been completely saturated and downward movement of excess water has practically ceased. Such a stage is reached generally in 48 to 72 hours after saturation. Sandy soils reach field capacity earlier than clayey soils. The downward movement of water continues even after this period for several days but the amount of water lost afterwards can be considered as negligible. Organic matter and fine texture increase the field capacity.

The field capacity is the upper most limit of available moisture range in soil water and plant relations. The force with which moisture is held at this point varies from  $-1/10$  to  $1/3$  of an atmosphere. However,  $-1/3$  atm is taken as a general value for field capacity.

#### Materials:

1. Straw mulch or a black polythene sheet
2. Spade
3. Water
4. Soil auger Moisture boxes
5. Physical balance, and Drying oven

#### Procedure:

Select a representative spot in the field. Ensure that water table is not within two meters from the layer of which field capacity is to be determined. Bund an area of about 2.5 sq. metres on all four sides and remove all weeds to avoid transpiration.

Pour water till the desired layers gets sufficiently wet. Spread straw mulch of at least 40 cm thickness on the surface to prevent evaporation. A polythene sheet can be conveniently used instead of a mulch.

Take soil samples from different layers up to the root zone depth with auger and determine the soil moisture content at every 12 to 24 hours interval till the values of two successive samples

are nearly equal. Plot the moisture content versus time curve on a graph paper. The lowest influx value can be taken to represent the field capacity of the value for field capacity is less than that for maximum water holding capacity, since the later measures the moisture present in a fully saturated soil resting on a water table, so that the soil pores are completely filled with water.

### Formula

$$\text{Percentage of soil moisture} = \frac{\text{Fresh wt} - \text{dry wt}}{\text{dry wt}} \times 100$$

The moisture percentage of a loam soil at 24 hours interval after saturation were observed as given below:

<b>24 hours after saturation</b>	<b>48 hours after saturation</b>	<b>72 hours after saturation</b>	<b>96 hours after saturation</b>
37.5%	28.7%	24.8%	24.7%

As in the above observation the moisture content after 72 hours is almost same as recorded at 96 hours. Therefore, the field capacity of the above soil is 24.8 per cent. It means that in this type of soil the field capacity reaches after 72 hours of saturation.

### Practical significance

### Conclusion

**Signature of Faculty In-charge**

**Determination of infiltration rate by double ring infiltrometer method**

**Aim**

To determine the infiltration rate

**Materials required**

1. Two Rings of 30 cm & 60 cm diameters
2. Hammer & Wooden board
3. Stop watch or timer
4. Hook or point guaze, spade, bucket, water

**Introduction**

Infiltration is the entry of fluid from one medium to another. In irrigation practice it is the term applied to the process of downward entry of water into the soil.

Infiltration rate is defined as the amount of water flowing into the soil profile per unit of soil surface per unit time. At the initial stage, when the soil is dry then the infiltration rate tends to be high but slowly it tends to decrease and becomes constant which can be called as basic intake rate or steady state infiltration rate.

The decrease in infiltration rate can be due to non – preventable decrease in matric solution gradients. The infiltration rate depends on the time of irrigation or rainfall initial soil wetness soil surface conditions hydraulic conductivity and soil profile. this method is used because of its accuracy and simplicity in measurement.

A double ring infiltrometer consists of 2 concentric metal rings. The rings are driven into ground and filled with water. The outer ring prevents the divergent flow of water. The drop in water level in the ring is useful in measuring the infiltration level.



## Working principle

A double ring infiltrometer requires two rings: an inner and outer ring. The purpose is to create a one-dimensional flow of water from the inner ring, as the analysis of data is simplified.

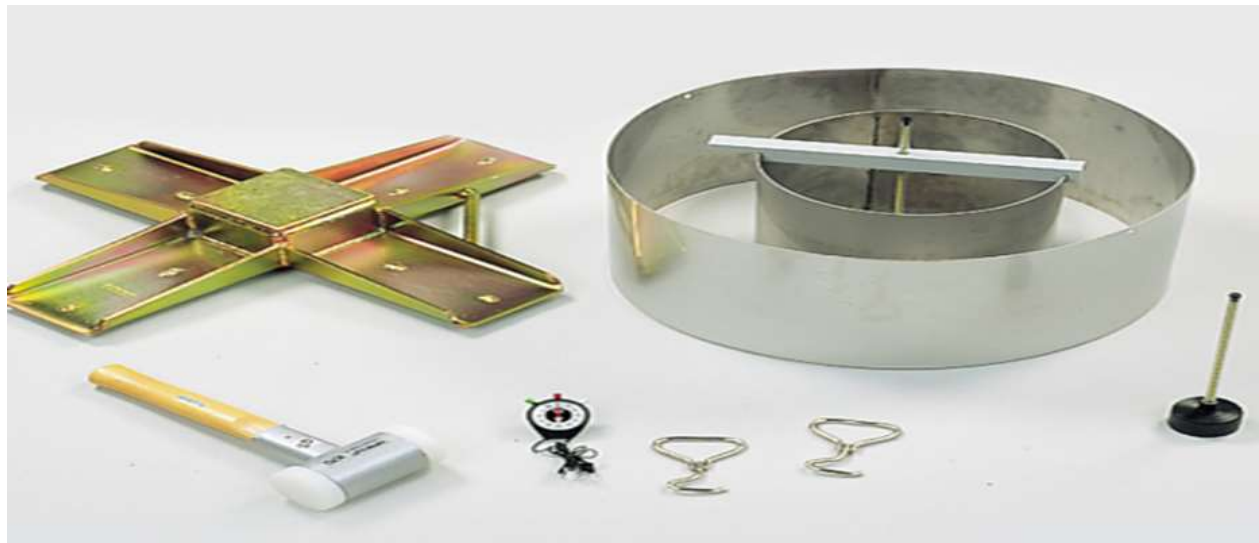
If water is flowing in one-dimension at steady state condition, and a unit gradient is present in the underlying soil, the infiltration rate is approximately equal to the saturated hydraulic conductivity.

An inner ring is driven into the ground, and a second bigger ring around that to help control the flow of water through the first ring.

Water is supplied either with a constant or falling head condition, and the operator records how much water infiltrates from the inner ring into the soil over a given time period.

The ASTM standard method specifies inner and outer rings of 30 and 60 cm diameters, respectively.

## Diagram sketch of double ring infiltrometer



## Procedure

1. Characterize soil condition in terms of texture, surface condition, structure, initial moisture status etc.
2. Prepare a level testing area.
3. Place outer ring in place; place flat board on ring and drive ring into soil to a minimum depth of 10 cm.
4. Place inner ring in the center of outer ring; place flat board on ring and drive ring into the soil to a minimum of 10 cm. the bottom rim of both rings should be at the same level.
5. Seal any large gaps along edges of the ring with 'putty' made from moist, reworked soil rolled out to the thickness of a pencil (subsoil is best). Take care not to disturb the surface of the soil inside the ring.
6. Pour the water in the outer as well as inner ring until water level indicator mark. Remove the splash guard after pouring water. Avoid any soil disturbance while pouring water by placing a splash guard. Maintain the same water head in both the rings. Do not fill excess water beyond the point gauge.
7. Record the fall (recession) in water level in the inner cylinder as a function of time at fixed intervals. For instance, at 1, 3, 5, 10, 20, 30, 40, 60, 80, 100, 120 and thereafter on hourly basis till the water intake is constant.
8. Measurement of the water level in the inner ring should be made from a fixed reference point and should continue at the interval determined under a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of 5mm or less of drop between the highest and lowest readings of four consecutive readings.
9. Enter the infiltration data in the given format and calculate the infiltration rate.
10. Plot the infiltration rate and cumulative infiltration curve as a function of time. The drop occurs in the inner ring during the final period or the average stabilized rate, expressed as mm or hour, should represent the infiltration rate for the test location.
11. The drop that occurs in the inner ring during the final period or the average stabilized rate is expressed in mm/hour.



**Observation:**

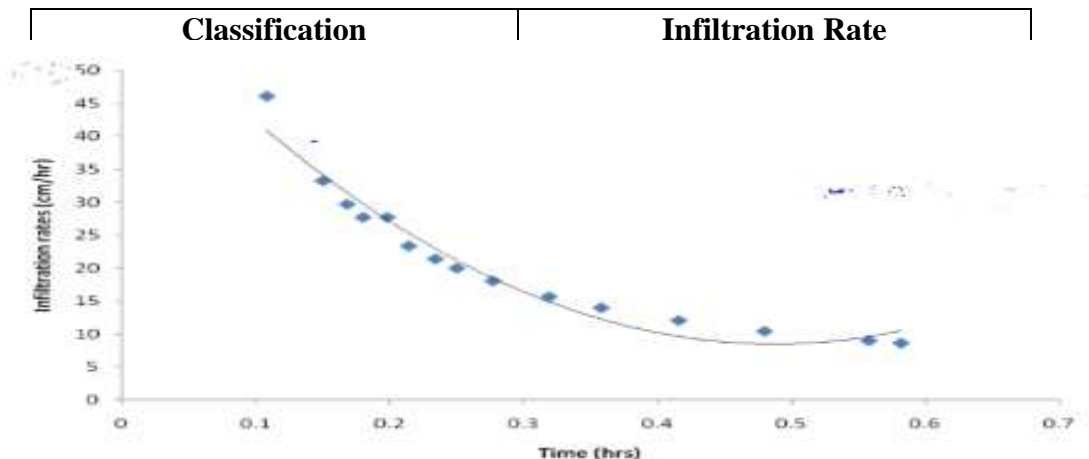
Location -

Test date –

Soil texture -

Time elapsed from previous rain –

Watch reading (hrs:min)	Time interval (min)	Cumulative time (min)	Water level before	Water level after	Infiltration (mm)	Infiltration rate (mm/min)	Infiltration rate (mm/hr)	Cumulative infiltration (mm)
2:05	0	(0+0) =0	100	0	0	100/0=0	0×60=0	(0+0) =0
2:07	2	(0+2) =2	100	93	(100-93) =7	7/2=3.5	3.5×60=210	(0+7) =7
2:10	3	(2+3) =5	94	89	(94-89) =5	5/3=1.6	1.6×60=96	(7+5) =12
2:15	5	(5+5) =10	88	80	(88-80) =8	8/5=1.6	1.6×60=96	(12+8) =20
2:25	10	(10+10) =20	79	70	(79-70) =9	9/10=0.90	0.90×60=54	(20+90) =29
2:35	10	(20+10) =30	69	60	(69-60) =9	9/10=0.90	0.90×60=54	(29+9) =38
2:45	10	(30+10) =40	59	48	(50-44) =6	6/10=0.60	0.60×60=36	(38+11) =49
3:05	20	(40+20) =60	47	38	(47-38) =9	9/20=0.45	0.45×60=27	(49+9) =58
3:25	20	(60+20) =80	37	30	(37-30) =7	7/20=0.35	0.35×60=21	(58+7) =65



## Infiltration graph

### Precautions

- Do not disturb the soil inside the rings
- Ensure that both the rings are placed at the same height.
- Do not let the rings get dry, pour water if needed.

### Practical significance

Soil can be excellent temporary storage medium for water, depending on the type and condition of the soil. Proper management of the soil can help maximize infiltration and capture as much water as allowed by a specific soil type. If water infiltration is restricted or blocked, water does not enter the soil and it either ponds on the surface or runs off the

land. Thus, less water is stored in the soil profile for use by plants, Runoff can carry soil particles and surface applied fertilizers and pesticides off the field. These materials can end up in streams and lakes or in other places where they are not wanted. Soils that have reduced infiltration have an increase in the overall amount of runoff water. This excess water can contribute to local and regional loading of streams and rivers or results in accelerated soil erosion of fields.

**Conclusion**

**Signature of Faculty In-charge**

## **Determination of Permanent Wilting Point (PWP) by Sunflower Method**

Permanent Wilting Point (P.W.P.) is the moisture content in percentage of a oven dried soil at which nearly all plants wilt and do not recover in a humid dark chamber unless water is added from an outside source. This is the lower limit of available moisture range for plant growth. Below the wilting point, extraction of moisture continue for some time but growth ceases completely. The force with which moisture is held by the soil at this point corresponds to about - 15 atmospheres.

### **(i) Determination of Wilting Point by Sunflower Method**

#### **Materials:**

1. Five 600 g capacity cans with lids
2. Sunflower seeds
3. Glass tubing (5 cm x 0.5 cm)
4. Sealing wax
5. Moisture cans
6. Physical balance
7. Drying oven
8. Bell jars or cabinet 25 cm x 50 cm with polythene cover
9. Water trays and
10. Soil sampler

#### **Procedure:**

Even though nearly all plants wilt at the same moisture content, some of them show clear signs of wilting while others do not. Dwarf sunflower is selected as an indicator plant in this method as it exhibits symptoms of moisture stress clearly and has a root system which penetrates throughout the soil mass uniformly and rapidly.

Fill uniformly five cans having a drain hole at the bottom with about 500 g of air-dry soil in each. It is necessary to have many replications in this trial as the permanent wilting point is a range of moisture. Sow about four seeds of sunflower in each and allow them to germinate.

After emergence, thin the plants to two, allow them to pass through the two holes in the lid and place the lid. Avoid heating of the cans due to insulation, by placing them in moist sawdust. Grow them for about six weeks, watering them as and when necessary. By this stage, the plants would have developed at least about three pairs of leaves.

Insert a glass tubing in the soil for aeration and plug it with cotton wool. Seal the soil surface with wax. Also close the drainage hole and seal it.

At this stage, water the plants for the last time and plug all the space between the soil surface and the holes in the lid of the can, be plugged with cotton wool to control evaporation. Allow the plants to wilt.

As soon as both the plants show signs of loss of turgor, transfer them to a dark humid chamber. The cans with plants can be kept in a small water tray and covered with a bell jar or a wire cabinet to create a high humidity chamber. The bell jar or the cabinet should be covered with a black polythene piece. The aim is to close the stomata and reduce transpiration.

Leave the plants overnight to gain a favorable water balance by allowing them to extract moisture from the soil. If they gain turgidity, expose them to the atmosphere for a couple of hours and transfer them back to the humid chamber. Repeat the process till the plants do not recover in the dark humid chamber.

At this stage, remove the lid and cut the plants. Take a duplicate soil sample. Remove the roots. Determine the moisture content of the soil samples which will present the value of the wilting point of the soil.

### **Practical significance**



**Conclusion**

**Signature of Faculty In-charge**

## **Determination of Field capacity and Permanent Wilting Point by Pressure Plate Apparatus and Hygroscopic Coefficient**

In our agricultural operations, mainly in scheduling irrigation we are interested to know the lower and the upper limit of available soil water (ASW). Lower limit of available soil water is known as permanent wilting point (PWP) or soil water potential,  $T_w$  of -15 bars; upper limit field capacity (F.C.) at which  $P_w$  is -1/3 bar. If we get soil moisture values from -1/3 to -15 bars, we can prepare the curve.

For irrigation we are interested in -1/3 and -15 bars. Though the water potential at field capacity may range from -0.1 to -0.5 bar in different types of soils, but the water content at -1/3 bar is generally taken as field capacity of the soil. Similarly, water content at -15 bar is considered as permanent wilting percentage. By determining the moisture content at -1/3 and -15 bar we get the values of field capacity and permanent wilting percentage in the laboratory. Besides the values of field capacity and permanent wilting point, pressure plate apparatus is a device to find moisture retention relationship of soil in laboratory.

### **Apparatus and Accessories:**

1. Pressure Plate Apparatus
2. Compressed air source
3. Rings to hold soil: should be of 1 cm height and 4-6 cm diameter
4. Physical balance
5. 105 °C oven
6. Moisture boxes
7. 50 ml burette

### **Procedure:**

1. Arrange the soil sample retaining rings evenly on the porous ceramic plate and fill them uniformly with processed air-dry soil. One sample retaining ring takes about 20 gm of dry soil. Segregation of particles of various sizes can be avoided by dumping of whole soil in a

ring rather than slow pouring. The capacity of a sample retaining ring should, therefore, be checked beforehand for the purpose.

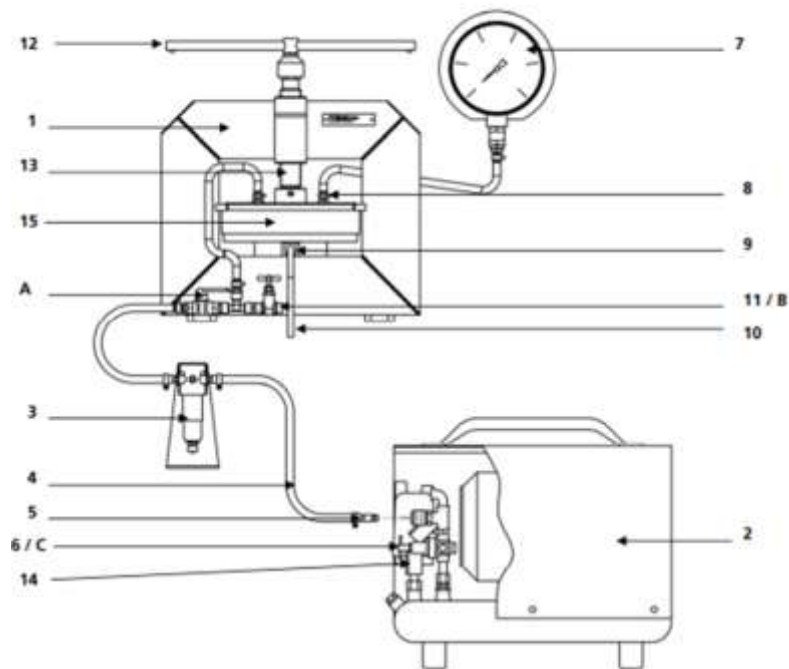
2. Fill the plate with distilled water and leave it for few hours for complete saturation of the plate and soil samples.
3. Drain off excess free water with pipette from around the soil samples.
4. Place triangular support on bottom of pressure chamber.
5. Place the porous plate with saturated samples on triangular support in the chamber and connect it to the lowest outlet port. The second plate is set on three plastic spacers which are placed on the first plate near the outer edge and located at about  $120^\circ$  from each other. Connection to this plate is made through middle outflow port. The third plate is similarly mounted and connection is made through the out let port on upper edge.
6. Connect the outflow tube to the burette and cover the pressure chamber with lid.
7. Tighten the clamping screws diagonally with 10-foot pound torque. Use torque wrench for uniform tightening.
8. Turn on about 2 psi air pressure in the pressure chamber. (Make sure that burette is also turned on before pressure is turned on). Immediately lot of air and water will rush out into the burette. Wait till air bubbles cease.
9. Gradually raise the pressure to desired level (1 atm = 14.7 psi one bar approximately). Now air bubbles will come very slowly at the rate of about 1 ml/minute. Faster air escape indicates leak and that must be corrected by resetting the apparatus.
10. Record water level in burette every morning and evening till the outflow of water stops completely. (Water level in burette should be noted immediately after escape of air bubble, which slowly forms at its surface).
11. Disconnect the burette and slowly release the pressure.
12. Open the lid of pressure vessel by unscrewing the clamping bolts.
13. Transfer the sample from one ring to weighed moisture box and record the wet weight of soil quickly without appreciable loss of moisture.

14. Dry the soil sample at 105 °C, find out dry weight of soil and calculate moisture in soil on dry weight basis.
15. Repeat the steps 6 to 14 seven times, applying the pressure of 4.9, 9.8, 14.7, 29.4, 73.5, 220.5 psi one after another at step 9.
16. Plot a desorption curve from the pressures and corresponding moisture data.

**Important Note:** For determination of Field Capacity by Pressure Plate Membrane Method, Pours Ceramic plate should be selected of -1/3 bars.

**Hygroscopic coefficient:**

## Diagram sketch of Pressure plate



- |                         |                |
|-------------------------|----------------|
| 1. Membrane apparatus   | 8. Mouth piece |
| 2. Compressor           | 9. Tube tulle  |
| 3. Air filter           | 10. Drain tube |
| 4. A high-pressure tube | 11. T-piece    |
| 5. Mouth piece          | 12. Handle     |
| 6. Reduction valve      | 13. Worm screw |
| 7. Manometer            | 15. Casing     |

Observations

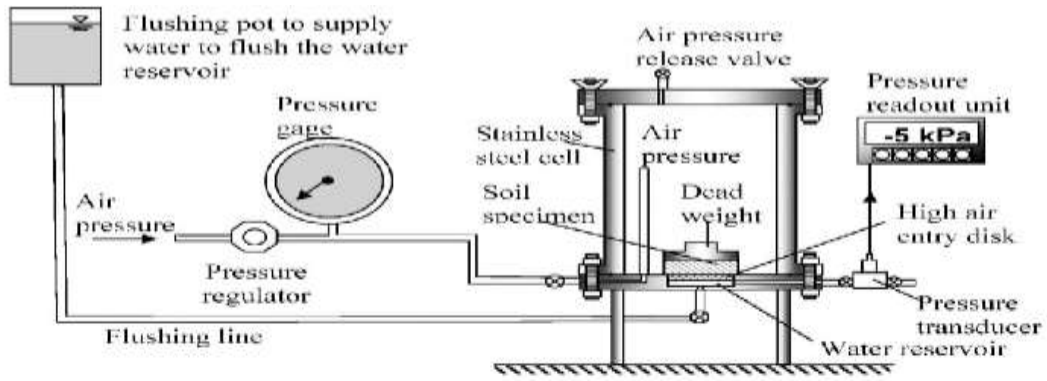
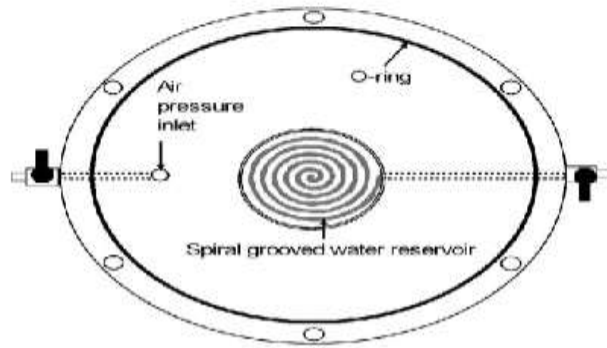


Fig. 1. Modified pressure plate apparatus for matric suction measurement

:

A)



u

lars of soil sample

B) Description equilibrium

Sr. No.	Date	Time	Pressure (psi)	Plate No	Burette reading	Total out flow(ml)

Practical significance:

**Conclusion:**

**Signature of Faculty In-charge**

## Experiment No. 5

Date-----

### Determination of maximum water holding capacity of soil

The maximum amount of water retained by soil per unit of its dry weight after the gravitational flow has ceased is called water holding capacity or field capacity of the soil. The water holding capacity varies in different type of soils and depends upon the types of soil particles and porosity of the soil. Sandy soils have poor water holding capacity then the loam and clay soils.

**Aim:** To study the water holding capacity of different soil.

#### Requirements:

1. Garden soil
2. roadside soil
3. measuring cylinders
4. funnels, filter papers
5. beakers
6. balance

#### Procedure:

Take two funnels and line them with filter paper. Label them A and B. Place them on measuring cylinders. Take 100 gm dried sample each of the garden soil and roadside soil. Put the garden soil in funnel A and roadside soil in funnel B. Pour 100 ml of water in each funnel. Record the volume of filtered out water in the measuring cylinder when the dripping of water stops from the funnel.

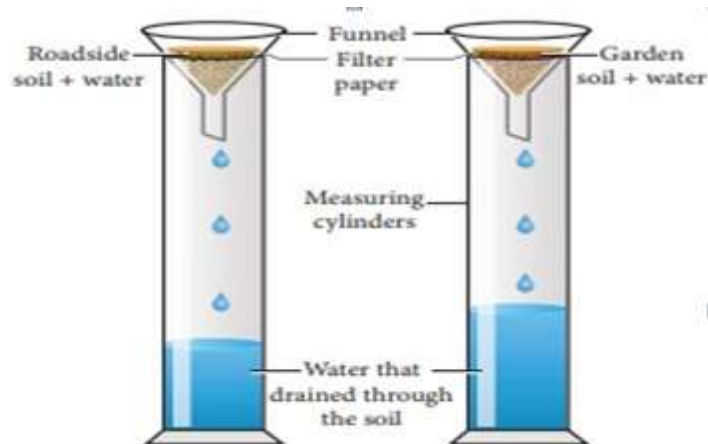




Figure: Water holding capacity of different soil

**Observation:**

Record the observation in the table as follows:

S. No.	Soil Types	Weight of soil (X)	Volume of water poured (Y)	Volume of water collected in measuring cylinder (Z)	Volume of water retained by the soil (Y-Z)	Water holding capacity of the soil in percentage $(\frac{Y-Z}{X} \times 100)$
1.	Garden soil					
2.	Roadside soil					

**Inference:**

Garden soil has a high-water holding capacity than the roadside soil, because roadside soil has larger quantities of sand and silt.

**Precautions:**

- Weighing of soil samples should be done accurately.
- Pour water slowly and gently on the soil in the funnel
- Record the volume of collected water in the measuring cylinders carefully.

**Practical significance:**

**Conclusion**

**Signature of Faculty In-charge**

## **Measurement of matric potential using gauge and mercury type tensiometer**

### **Aim:**

To Install and know the working principle of tensiometer in crop field.

### **Materials required**

1. Tensiometer
2. Water
3. Screw auger or coring tool
4. Aluminum moisture box
5. Spade
6. Bucket

### **Introduction**

The tensiometer is an instrument designed to provide a continuous indication of the soil moisture tension. As the water potential in tensiometer comes in equilibrium with the soil water, the tensiometer represents the matric potential of the soil. The available soil moisture range is upto 15 atm. This device typically consists of a glass or plastic tube with a porous ceramic cup, and is filled with water. This device typically consists of a glass or plastic tube with a porous ceramic cup, and is filled with water. The top of the tube has either a built-in vacuum gauge or a rubber cap used with a portable puncture tensiometer instrument, which uses a hypodermic needle (sharp and hollow needle) to measure the pressure inside the tensiometer.

### **Working principle**

When buried in the soil the ceramic tip of the tensiometer allows water to move freely in or out of the tube. As the soil dries out, water is sucked out through the porous ceramic tip, creating a partial vacuum inside the tensiometer which is read on the vacuum gauge. When the soil is wetted by sufficient rainfall or irrigation, water flows back into the tensiometer, the vacuum decreases and the gauge reading is lowered.

Tensiometer measures how tightly water is held to the soil particles and not how much water is

left in the soil. A sandy soil will reach a high tension sooner than a clay loam because sandy soils cannot supply as much water to the plant and it is used up more quickly. As soil moisture is depleted by plant uptake, or as it is replenished by rainfall or irrigation, corresponding readings on the tensiometer vacuum gauge occurs.

Tensiometers do not operate in dry soil because the pores in the ceramic tip drain and air is sucked in through them breaking the vacuum seal between the soil and the gauge on top of the tensiometer. Such tensiometers are used in irrigation scheduling to help farmers and other irrigation managers to determine when to water. In conjunction with a water retention curve, tensiometers can be used to determine how much to water. Soil tensiometers can also be used in the scientific study of soils and plants.

## **Procedure**

1. Select a representative spot in the cropped field, usually between plants within a row for convenience during Intercultural operations.
2. Make a vertical hole equal to the cup diameter to the desired depth using a screw auger or a coring tool.
3. Carefully remove the auger, making sure no rocks fall back in to the hole. Sometime pouring water along the driving shaft helps in easy coring of the hole,
4. Collect the soil in an aluminum box. Prepare thick slurry of the collected soil and pour it in to the hole.
5. Prepare the tensiometer for installation. Fill the tensiometer with distilled water. Observe for any air gaps/air bubbles in the tube.
6. Hitting the top of the tensiometer with an open palm will also dislodge any air bubbles from the side of the tensiometer.
7. Replace the cap, twisting until the stopper reaches the bottom of the reservoir. You do not need to turn it too hard.
8. Place the cup of the tensiometer in the mouth of the cored hole. Force the cup into the hole by pushing directly down on the cap. Do not wobble or rotate the tensiometer shaft and do not push on the gauge. After properly positioning the cup of the tensiometer maintain at least 3 cm between the bottom of the gauge and the soil surface.
9. After positioning the cup properly, place a small amount of water into the bottom of the hole

and allow it to soak in. This ensures proper contact of ceramic cup with the soil.

10. Build a mound around the tensiometer to prevent water from running directly down the side of the tensiometer
11. Allow the tensiometer to attain equilibrium and start monitoring the soil water tension reading in the vacuum gauge.
12. Record the soil water tension readings in the vacuum gauge at the same time each day, in the early morning.
13. From the soil moisture characteristic curve estimate the soil water content with respect to the soil moisture tension measured by tensiometer.

**Draw a neat sketch showing the working principle of tensiometer**

### **Tensiometer Observations**

<b>Depth of soil (cm)</b>	<b>Vaccum guaze reading (centibar)</b>	<b>Soil moisture content (%)</b>	<b>Remark</b>
<b>30 cm</b>			
<b>45 cm</b>			
<b>60 cm</b>			

## Calibration of Tensiometer

The relation between tensiometer and soil moisture percentage is given by the following equation:

$$Y=c+b\log X$$

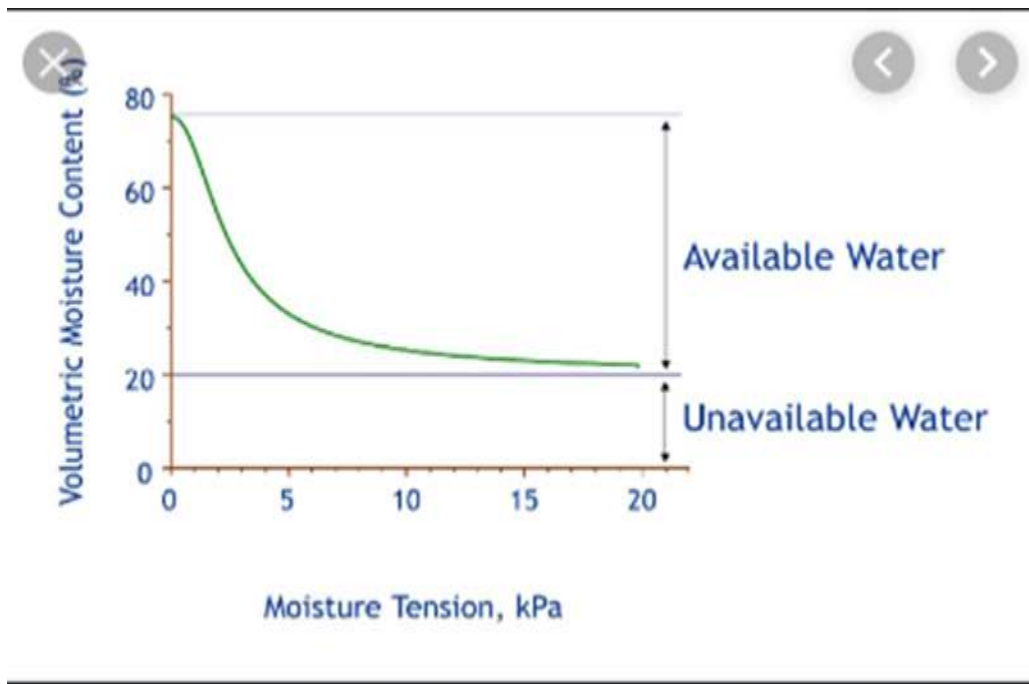
Where, Y, is the moisture percentage,

b & c are constants and

X, is the tensiometer reading.

The best way of tensiometer calibration against moisture percentage is by installing in field then recording tension readings and soil moisture content by Gravimetric method. Data are plotted of graph paper and their corresponding soil moisture readings on oven dry basis and thus, a curve prepared for guidance.

## Draw soil moisture content graph



## Precautions

Before tensiometers are buried in the soil, the ceramic tip and tube must be placed in a container of water for 24 hours or atleast 12 hours to ensure that the tip is fully wet. Tensiometers must remain in the container of water until installed.

The tensiometer tube must be filled with water to the top before installation and at each reading the water level in the tensiometer must be checked.

### **Practical significance**

Tensiometer provides soil moisture tension readings rapidly in-situ. The instrument is relatively simple and robust. The soil moisture tension is a measure of the tenacity with which water is retained in the soil and is related to the amount of water in the soil that is available to plants. It reflects the force per unit area that must be exerted by plant roots to extract water from the soil. Further scheduling irrigations based on tensiometric readings maximizes irrigation efficiency by minimizing runoff and percolation losses. This often results in lower energy and water use and optimum crop yields.

### **Conclusion**

**Signature of Faculty In-charge**

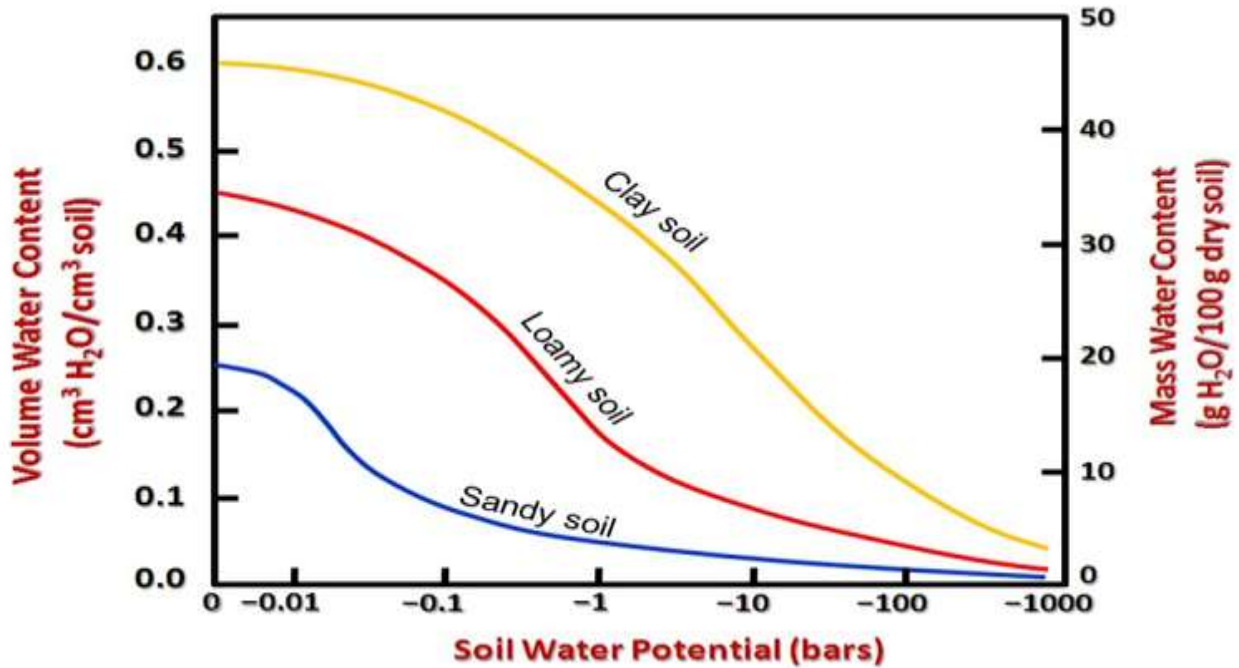
**Soil Moisture Characteristic Curve**

**Aim:** To determine Soil Moisture Characteristic Curve

**Soil Moisture Characteristic Curve**

Soil moisture characteristic curve is the relationship between the water content and the soil water potential ( $\Psi$ ). It describes the functional relationship between soil water content and its energy status in terms of its matric potential under equilibrium conditions. This curve is characteristic for different types of soil. It is also called the Water retention curve. A soil water characteristic (SWC) curve describes the amount of water retained in a soil (expressed as mass or volume water content,  $\Theta_m$  or  $\Theta_v$ ) under equilibrium at a given matric potential. A SWC is an important hydraulic property related to size and connectedness of pore spaces. It is strongly affected by soil texture and structure, and by other constituents including organic matter. Modeling water distribution and flow in partially-saturated soils requires knowledge of the SWC. It plays a critical role in water management and in prediction of solute and contaminant transport in the environment. The SWC function is highly nonlinear and relatively difficult to obtain accurately. The matric potential extends over several orders of magnitude for the range of water contents commonly encountered in practical applications, it is often plotted on a logarithmic scale. The SWC is a primary hydraulic property required for modelling water flow in porous materials. It is used to predict the soil water storage, water supply to the plants (field capacity) and soil aggregate stability. Due to the hysteretic effect of water filling and draining the pores, different wetting and drying curves may be distinguished. At potentials close to zero, a soil is close to saturation, and water is held in the soil primarily by capillary forces. As  $\Theta$  decreases, binding of the water becomes stronger, and at small potentials (more negative, approaching wilting point) water is strongly bound in the smallest of pores, at contact points between grains and as films bound by adsorptive forces around particles. Early conceptual models for SWC curve were based on the "bundle of cylindrical capillaries" (BCC) representation of pore space geometry (Millington and Quirk, 1961). The BCC representation postulates that at a given matric potential a portion of interconnected cylindrical pores is completely liquid filled, whereas larger pores are completely empty.





## Factors influencing soil water retention

1. Soil structure (pb, aggregate size distribution)
  - a) Important at low suctions, 0 to 50 kPa
  - b) Capillary effects
2. Clay content
  - a) Positively related to surface area of soil particles
  - b) Positively related to water adsorption
  - c) Dominant factors at high suctions

## Practical Significance

## Conclusion

Signature of Faculty In-charge

## **Determination of saturated hydraulic conductivity by constant and falling head method**

### **Aim:**

Determine the coefficient of permeability of a re-moulded coarse grained soil sample with a constant head permeameter.

### **Materials required**

1. Permeameter mould with or without collar
3. Tot cap with water inlet nozzle, air release valve
4. Perforated top and bottom plates
5. Constant head tank
6. Bottom tank
7. Tamping rod
8. Stop watch, scale, measuring cylinder, spanner, grease, thermometer, etc.

### **Introduction**

The coefficient of permeability (k) of a soil is defined as the rate of discharge of water through a unit cross sectional area of a soil under unit hydraulic gradient for a laminar flow condition. This can be determined in the laboratory by constant head permeability test for coarse grained soil with k value greater than  $10^{-3}$ cm/sec.

### **Working principle**

The hydraulic conductivity of a soil is a measure of the soil's ability to transmit water when submitted to a hydraulic gradient. Hydraulic conductivity is defined by Darcy's law, which, for one-dimensional vertical flow, can be written as follows:

### **Field method with falling head permeameter**

$$Q = K \frac{A\Delta H}{L}$$

Where,  $Q$  = volume of water flow per unit time ( $\text{cm}^3/\text{s}$ )

$V$  = Darcy's velocity ( $\text{cm}/\text{s}$ )

$\Delta H = h_1$  and  $h_2$  are hydraulic heads, and  $L$  is the vertical distance in the soil through which

flow takes place.

$K$  = The coefficient of proportionality, in the equation is called the hydraulic conductivity

$L$  = length of flow

### Field method with variable head permeameter

$$K = \frac{2.3aL}{A} \log_{10} \frac{h_1}{h_2}$$

Where,  $L$  = flow length ( $\text{cm}$ )

$A$  = cross-sectional area of glass tube ( $\text{cm}^2$ )

$A$  = cross-sectional area of soil core ( $\text{cm}^2$ )

$t$  = time interval ( $\text{s}$ )

$\Delta H = h_1$  and  $h_2$  are hydraulic heads,

$K$  = The coefficient of proportionality, in the equation is called the hydraulic conductivity

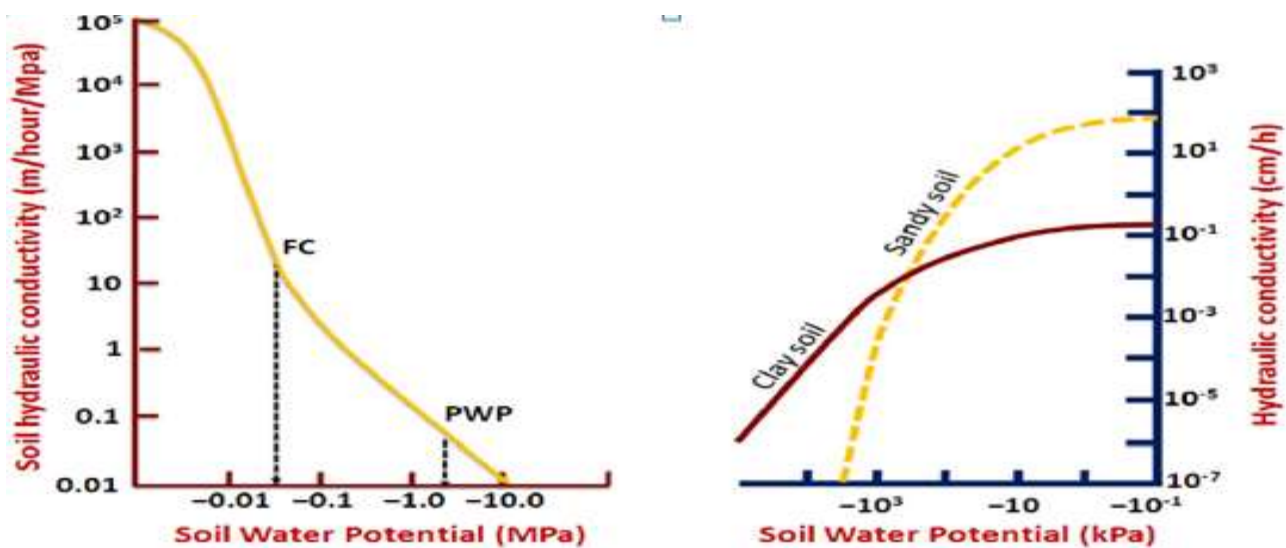


Figure: Soil hydraulic conductivity

## Diagram sketch of hydraulic conductivity



### Procedure

1. Remove the oversize a particle by sieving the soil specimen through IS 20 mm sieve and determine its percentage (%).
2. Note the dimensions of the permeameter and calculate its volume.
3. For testing re-moulded soil sample, first calculate the amount of dry soil and water required to achieve a particular density and moisture content.
4. Mark the height of mould into three equal parts and also divide the soil into three equal parts.
5. Compact the soil into the mould in layers after fixing the mould to its base plate containing porous stone and placing the collar on top.
6. Put the porous stone on the top of the soil and fix the top plate which is provided with an inlet valve and air cock. Secure both the base plate and the top plate to mould with suitable clamps and rubber gasket to make the entire assembly water tight.
7. Place the assembly in a shallow metal tray with an out-let .Fill the tray with water submerge the base plate completely. All the heads of water must be measured with respect to the tail water level corresponding to the centre of the out-let pipe or crest of the outlet in tray.
8. Attach the constant head water tank with the sliding bracket to a vertical stand. This tank has three opening connect one of them to water supply source, the second to the overflow

tube and the third to the inlet valve provided on the cap of the permeameter. Remove all the air bubbles with the help of the air cock, provided on the top plate. Allow the soil sample to saturate. Check this by obtaining constant values of discharge collected over a given time under a given head.

9. When steady state flow is attained, collect sufficient quantity of water (about 250cc ) and note the time interval. Take two to three observations.
10. Note the total head loss and the length of specimen and note the temperature of water.
11. Repeat the test for three different hydraulic heads covering the full range of head in the apparatus.

### **Tabulation Variable Head or Fall Head Permeability Test**

#### **Observations**

<b>flow length (cm) (L)</b>	<b>Head (h1) cm</b>	<b>Head (h2) cm</b>	<b>cross-sectional area of glass tube (cm<sup>2</sup>) (a)</b>	<b>Time (sec) (T)</b>

#### **Calculation**

The permeability at the test temperature can be found at by the following formula

## **Precautions**

- This apparatus is for research applications only and needs to be operated by qualified operators.
- Other use than intended purposes should be avoided.
- Take care for personal hygiene and environmental precautions in case of operating contaminated samples.
- Apparatus is rated for indoor lab locations only.

## **Practical significance**

The reports of permeability test shall include the following information:

- (a) Grain size analysis, maximum particle size, and percentage of any over-size material not used
- (b) Dry unit weight, void ratio,
- (c) Average value of permeability obtained.

## **Conclusion**

**Signature of Faculty In-charge**

**Determination of hydraulic conductivity of saturated soil below the water table by augerhole method**

The inverted auger hole method is used to measure hydraulic conductivity in situ above the water table. A hole is bored using an auger to a certain depth. Before the test is undertaken, the bore is filled with water to create near saturated conditions around the bore. Water is again filled in the hole to a certain level and the fall in water level at different times and its rate is recorded (Fig. 10.1).

$$k = 1.15 r \frac{\log\left(h(t_1) + \frac{r}{2}\right) - \log\left(h(t_n) + \frac{r}{2}\right)}{t_n - t_1}$$
$$= 1.15 r \tan \alpha$$

Where,  $r$  = radius of auger hole; cm:

$h(t)$  = Water level in the hole at time  $t$  cm

**Requirements**

1. Auger
2. Steel tape for measurement of water level
3. Float
4. Water

**Procedure**

1. Drill a bore hole with an auger up to a certain depth;
2. Fill water in the hole 2-3 times and leave it for 2-3 hours to create near saturated conditions in and around the hole;
3. After obtaining saturated conditions, record the falling water levels in bore hole at different time intervals;
4. Plot  $\left[h(t) + \frac{r}{2}\right]$  against time 't' on semi-log paper and read the value of tangent  $\alpha$  (Fig. I 0.2); and using equation 10.1, compute the value of hydraulic conductivity.

## Observations and Calculations

### Example

Compute hydraulic conductivity of a soil using inversed auger hole. The diameter of hole was 5 cm and depth of hole from reference level was 100 cm (Fig.10.1).  $r = 2.5$  cm  $D = 100$  cm

i	t i, sec	h' (t), cm	h (t), cm	h (t.) + r12, cm
1	0	80	20	21.25
2	30	82	18	19.25
3	60	84	16	17.25
4	120	86	14	15.25
5	220	88	12	13.25
6	400	90	10	11.25
7	520	92	8	9.25
8	720	94	6	7.25
9	920	96	4	5.25

$$\text{Solution: } \tan \alpha = \frac{\log 66 - \log 5}{1000}$$

$$= \frac{1.82 - 0.698}{1000}$$

$$= \frac{1.12}{1000} = 0.00112$$

$$K = 1.15 \times r \times \tan \alpha$$

$$= 1.15 \times 2.5 \times 0.00112$$

$$= 0.00322 \text{ cm/sec}$$

$$= \frac{0.00302}{100} \times 3600 \times 24 = 2.78 \text{ m/day}$$



**Results:**

Hydraulic conductivity = \_\_\_\_\_m day

**Precautions:**

- Bore hole should be straight to facilitate the movement of float and tape
- In order to measure fairly accurate value of hydraulic conductivity near saturated conditions need to be obtained.

**Conclusion**

**Signature of Faculty In-charge**

## Experiment No.10

Date-----

### Determination of effective rainfall

#### Aim

To study about measurement of rainfall

#### Materials required

1. Ordinary rain gauge
2. Pen
3. Note book

#### Introduction

Water in any form falling on the earth is called precipitation. The main forms of precipitation falling to the ground are drizzle, rain, snow and hail. Rain is the liquid form of precipitation, while snow and hails consist of solid ice crystals. Dew and frost are ground precipitation, which do not fall but form near and ground on the vegetation. Rain is an import form of precipitation and is the main source of soil moisture for crop production.

#### Rainfall measurement

The principle of rainfall measurement is to measure the depth of the layer of the water that has fallen. Five millimeter of rain means if that rainfall is collected on flat surface, the height of water would have been 5 mm.

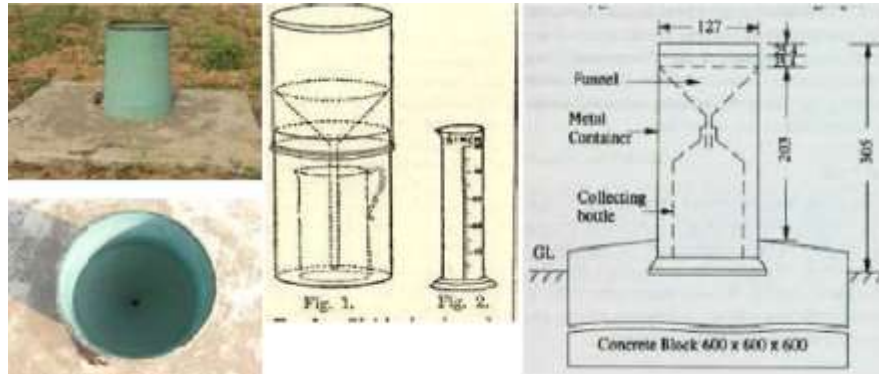
#### Ordinary rain gauge

This rain gauge consists of a funnel, provided with a rim, which is circular and exactly 127 mm in diameter. The rim of the rain gauge is 30 cm above the ground level and 25.4 cm above the cemented plat form. The rain water collected in receiver is measured with the help of a standard measuring cylinder provided with the instrument. The capacity of the receiver is 4 litres. A measuring cylinder calibrated in mm is used to measure the rainfall. The measurement is taken daily at 8.30 hrs IST and 14.00 hrs LMT as and when there is rain. The rainfall of last 24 hrs is recorded in the column of observation day.

## Measurement of rainfall:

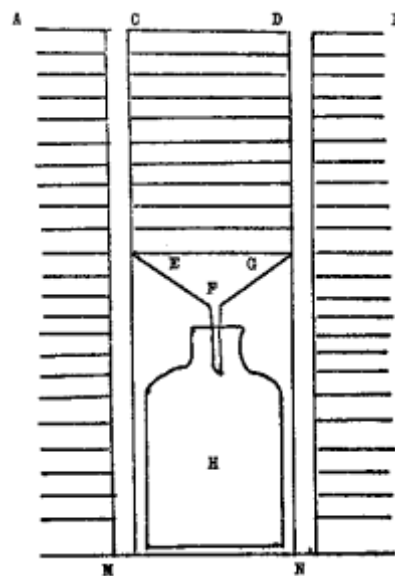
The rainwater from the receiver is carefully poured in to the measuring glass kept on the horizontal surface. The observer maintains his eye at the level of water in the measuring glass. Reading is noted from the lower meniscus avoiding parallax.

## Ordinary rain gauge



## Ramdas Method

Ramdas (1960) suggested a direct field method using a small portable device containing soil of the field, so eliminating the necessity of sampling.



Ramdas Apparatus for Measuring Effective Rainfall

The apparatus as shown, consists of a cylinder (CD) of about 30 cm in diameter, with a perforated base (BO) and a funnel (F) leading into a receiver bottle (H). All these parts are enclosed in an outer cylinder (MN). The cylinder (CD) is filled with a representative soil with the same density as that of the field. The height is equal to the depth of the effective root zone of the crop.

The apparatus is installed in the field crop where the effective rainfall is to be measured. The crop in the container is irrigated along with the field crop. Excess rain or irrigation water drains in the receiver bottle H and is measured from time to time. The total rainfall minus the ineffective rainfall gives the value of effective rainfall. It is assumed that there is no surface runoff. Cylinders of different lengths are used consistent with the rooting depth of the different crops. With a suitable number of replications, the method is very useful. It is simple and practical and furnishes direct readings.

### **Determination of the Effective Rainfall**

The amount, the intensity and the distribution of rainfall is important.

1. When rain water falls on the soil surface, some of it infiltrates into the soil, some stagnates on the surface, while some flows over the surface as runoff.
2. When the rainfall stops, some of the water stagnating on the surface evaporates to the atmosphere, while the rest slowly infiltrates into the soil.
3. From all the water that infiltrates into the soil, some percolates below the root zone, while the rest remains stored in the root zone.

In other words, the effective rainfall is the total rainfall minus runoff minus evaporation and minus deep percolation.

$$\mathbf{EF = Total\ rainfall - runoff - evaporation - deep\ percolation}$$

Only the water retained in the root zone can be used by the plants, and represents what is called the **effective part of the rainwater**.

The term effective rainfall is used to define this fraction of the total amount of rainwater useful

for meeting the water need of the crops.

Only 2 simple formulae are provided to estimate the fraction of the total rainfall which is used effectively. These formulae can be applied in areas with a maximum slope of 4-5%:

$$Pe = 0.8 P \text{ if } P > 75 \text{ mm/month}$$

$$Pe = 0.6 P \text{ if } P < 75 \text{ mm/month}$$

With,  $P$  = rainfall or precipitation (mm/month)

$Pe$  = effective rainfall or effective precipitation (mm/month)

**NOTE:  $Pe$  is always equal to or larger than zero; never negative**

## Observations

## Problems

1. Calculate the effective rainfall for the following months in mm

Sl. No.	Date	Rainfall (mm)	ET (mm)	Balance (mm)	Surplus (mm)	Cum.ER (mm)
1						
2						
3						
4						
5						
6						
7						
8						

<b>9</b>						
<b>10</b>						
<b>11</b>						
<b>12</b>						
<b>13</b>						
<b>14</b>						
<b>15</b>						
<b>16</b>						
<b>17</b>						
<b>18</b>						
<b>19</b>						
<b>20</b>						
<b>21</b>						
<b>22</b>						
<b>23</b>						
<b>24</b>						
<b>25</b>						
<b>26</b>						
<b>27</b>						
<b>28</b>						

<b>29</b>						
<b>30</b>						
<b>31</b>						
<b>Total</b>						

### **Precautions**

- The funnel should not get choked with dirt.
- The receiver should be always kept clean.
- The measuring glass should be kept spotless clean.
- All the parts should be examined regularly for choking and leakage.
- While replacing the funnel, see that it is pressed down evenly from all sides.

### **Practical significance**

This method was devised assessing crop evapotranspiration, percolation, effective and ineffective rainfall of a rice crop simultaneously under the field conditions.

### **Conclusion**

**Signature of Faculty In-charge**

**Determination of irrigation requirement of crops (calculations)****Scheduling of Irrigation by different Methods**

Irrigation scheduling is the process of determining when, how and how much water to be irrigated. Proper irrigation scheduling indicates the correct time (when to irrigate) and amount of irrigation water at each irrigation. It saves water and energy, boots up yield, and reduces the production cost. Time of irrigation is usually governed by major conditions namely (1) Water need of crops and (2) Availability of irrigation water. Water need of crops is, however, the prime consideration to decide the time of irrigation. There are several approaches for determining when to irrigate the crop. The approaches can be broadly classified into three groups:

- (1) Soil moisture regime approaches
- (2) Climatologic approaches
- (3) Plant indices

**(1) Soil moisture regime approaches:**

These approaches involve determination of water content of the soil and finding the deficit in available moisture at which it is proposed to irrigate based on pre- determined minimum water content and irrigating to bring the soil to field capacity. The soil moisture content can be known from the following methods:

**a) Gravimetric methods:**

This is a direct and reliable method, where samples are collected, weighed and dried at 105-110 °C for about 24 hours until constant weight is obtained and reweighed after drying. Details of this method are illustrated in Experiment No. 1.

**b) Feel and Appearance:**

Soil moisture content can be judged by feel and appearance of the soil, with experience. Soil samples from root zone depth are formed into balls, tossed gently into air and caught in hand. The accruing of judgement improves with experience.



## Tensiometers:

Use of tensiometers to determine soil moisture tension and relating to water content of the soil by the characteristic curve was already discussed in Experiment No.1 Electrical resistance

Tensiometers and electrical resistance, methods actually indicate the energy status of soil of water. These are not so popular because of some limitations. Tensiometers have narrow working range 1.0 to 0.8 bar tension whereas gypsum blocks do not work satisfactorily at low tensions.

It is computed by posting everyday ET, effective rainfall, soil water content etc and determining the balance of moisture in the soil. This method is cumbersome and lot of data is required.

Table: Guide for judging the amount of available soil moisture range by Feel and Appearance Method:

SI. No.	Available soil moisture range	Coarse texture soils moderately	Moderately coarse	Medium texture	Fine texture
1	Field capacity (100%)	Free water appears on soil, but wet outline is left on hand	Similar symptoms	Similar symptoms	Similar symptoms
2	75%to 100%	Tends to stick Together slightly sometimes forms a very weak ball under pressure	Forms weak ball breaks easy to not stick	Forms a ball is very pliable slickes readily	Easily ribbon out between fingers has slick feeling
3	50%to 75%	Appears to be dry don't form a ball on pressure	Tends to form ball on pressure but seldom hold	Forms a ball somewhat plastic sometimes	Forms a ball but ribbon out between thumb and

			together	slides with slight pressure	fore finger
4	25%to50%	As above but ball is formed by squeezing very firmly	Appears to be dry don't format ball unless squeezed very firmly	Somewhat crumbly but holds together with pressure	Somewhat pliable forms a ball under pressure
5	0%to 25%	Dry, loose. single grained, flows through fingers	Dry, loose, flows through fingers	Powdered dry but sometimes break down into powdery condition	Hard breaked cracked sometimes has loose crumbs on surface

### **Climatologic approach:**

The atmospheric dryness or evaporative demand of a place actually determines the amount of water transpired from a cropped field. Atmospheric evaporative demand can be estimated using various methods (Penmann's formula, Blannay and Criddle) and correlated with the actual crop water use. Prihar et al. (1974), suggested the use of ratio (s) between irrigation water (IW) and the cumulative pan evaporation (CPE) to schedule irrigation to crops under specific soil and climatic conditions. The quantity of water to be applied at each irrigation will depend on soil and crop characteristics. Dew corrections are to be made for effective rainfall received during the irrigation interval.

Example: Irrigation is schedule at í W/CPE ratio 0.8 and the crop is irrigated to a depth of 6.0 cm. CPE at which irrigation to be scheduled can be calculated as follows: 6.0 m

Depth of irrigation (IW)= 6.0m

$$\text{CPE} = X\text{cm}$$

$$\text{IW/CPE} = 0.8$$

$$\text{So, } \frac{6.0}{x} = 0.8$$

$$\text{So, } x = \frac{6.0}{0.8} = 7.5$$

This crop is to be irrigated when CPE is 7.5 cm

### **Plant indices:**

Monitoring plants is the most direct method of determining when to irrigate. Plant parameters have to be related to soil water content to determine the quantity of irrigation requirement.

### **Appearance and Growth:**

These are not effective parameters to decide the time; of irrigation because the plants exhibit visible symptoms of deficiency long after they experience moisture stress. Deficiency of water stress causes leaf and shoots wilting leaf colour, drooping of leaves and rolling of leaves.

### **Leaf Temperature:**

An infrared thermometer measures the difference between canopy and ambient temperature. The number of degrees by which canopy temperature exceeds air temperature each day is accumulated until a certain level (predetermined) is reached. When the level reaches, it is to be irrigated.

### **Leaf water potential:**

Leaf water potential indicates the plants need for water. Leaf water potential is measured by removing a leaf and placing it in a pressure chamber. The pressure in the chamber is slowly increased until fluid is forced from the leaf. The pressure used is a measure of the leaf's moisture potential. Lower potential indicates a greater need for water. The leaf age, leaf exposure to solar

radiation and time of day when leaf is sampled all significantly influence the results. This method is not extensively used since considerable time, care and training are required to obtain reliable results.

### **Stomata resistance:**

Leaf resistance to vapour diffusion into the atmosphere is primarily governed by the degrees of stomata closure, which under sufficient day light is mainly regulated by leaf water deficits. Stomata resistance is, therefore, an index to the need for water, since it is related to the degree of stomata opening and the rate of transpiration. High resistance generally indicates significant stomata closure, reduced transpiration rates and the need for water. Leaf diffusion parameters are used to measure stomata resistance. The skill required to take measurements and time involved to interpret limit the use of this method for research purposes.

### **Rough methods for farmers:**

Soil-cum-Sand Mini plot technique:

It is also known as Profile modifications. The principle involved in this method is to reduce artificially, the available water holding capacity of soil in root zone depth in the mini plot by mixing sand with it. Plants on sand mixed mini plot show moisture stress symptoms earlier than plants in rest of the area. Usually, an area of 1.0 m<sup>2</sup> is selected in the field and a pit of 1.0 m depth is excavated in layers of about 15 cm depths is excavated in layers of about 15 cm depths. Each layer of soil is mixed with 5 per cent by volume of sand and the pit refilled in the same sequence of layers as excavated by compacting each layer to bring bulk density of soil in the mini plot as that. of the surrounding area. Symptoms of plants in the mini plot indicate time for irrigating the crop.

### **Increased plant stand:**

An area of about 1.0 m<sup>2</sup>, preferably in a high spot, is sown with the same crop to maintain about four times the plant population compared with that in the surrounding area. Crop with high stand establishment wilts earlier than the crop in the rest of the field indicating timing of irrigation.

Reduction in growth rate of sensitive plant organs may indicate irrigation need of crops. In the case of orange plants, irrigation is given when the growth rate of fruit circumference falls below

0.2 to 0.3 mm day". Since stem elongation of crops like sugarcane, tomato and cotton is highly correlated with water stress, it is possible to use this character as an indication of irrigation needs. Relative leaf water content plant water potential, stomata resistance and plant temperature, which can adequately reflect the internal water balance of the plant, may be used as potential indicators for scheduling crop irrigation.

### **Problem:**

1. Schedule irrigation in crop (Name) based on pan evaporation of Pantnagar metrological laboratory on the basis of following points.

Irrigation water to be applied = 7.0 cm.

$$\text{IW/ CPE ratio} = 0.9$$

Date of sowing of (crop) wheat = 15 Nov. 2002

I<sup>st</sup> irrigation it means we will irrigate the wheat crop when CPE reaches 77.8 mm. In the above table CPE reaches 77.5 mm on 12<sup>th</sup> December 2002. therefore, irrigation will be given on 12<sup>th</sup> December.

Likewise, II<sup>nd</sup> irrigation and so and so.

### **Note:**

1-Irrigation treatments based on IW/ CPE ratio should be started after giving a common irrigation. 2- Effective rainfall should be considered while planning irrigation treatment based on IW/CPE ratio.

For winter R.F.x 1.66 Pan evaporation equivalent

For summer R.Fx1.25 = Pan evaporation equivalent

Pan equivalent should be subtracted from CPE and irrigation should be at same treatment CPE.

Adjustment of rainfall IW/CPE=ratio

IW=1 depth of irrigation water or irrigation water

IW/CPE =0.6 at this irrigation is scheduled

1.0

CPE=1.66 0.6

1.66x r.f. =x

Add in CPE of that treatment and delay the irrigation.

**Practical significance:**

**Conclusion:**

**Signature of Faculty In-charge**

**Determination of ET of crops by soil moisture depletion method and  
Determination of water requirements of crops (calculations)****Aim**

Construction of crop coefficient curves for important crops of the region and determination of crop evapotranspiration

**Crop Water Requirements:**

In designing an irrigation system, the primary objective is to know the water requirement of crops. Water requirement of crops are determined either by field cultivation or by estimation through commonly used empirical formulae such as Blaney Criddle, radiation, Penman or pan evaporation method.

**Definitions:****Crop water requirement or evapotranspiration ( $E_{T_{rep}}$ ):**

It may be defined as the rate of evapotranspiration of a disease-free crop growing in a field of not less than one hectare under adequate fertility and water supply so that full productive potential can be achieved in prevailing environment. Evapotranspiration requirement of a crop refers the ET and expressed in mm/day.

**Reference crop evapotranspiration (ET):**

It is the rate of evapotranspiration from an extended surface of 8-15 cm tall green grass of uniform height, actively growing, completely shading the ground and not short of water. ET, may be computed by using the empirical formulae and meteorological data for the specific period.

**Crop coefficient (K):**

It is the ratio of crop evapotranspiration,  $E_{Top}$ , and the reference crop evapotranspiration. ETs. when both apply to large field under optimum growth condition.

## **Ground Cover:**

Drip irrigation system is mainly used to irrigate orchard or row crops. At the young stage of crops the most of fields remain unshaded. It is more usual to wide spaced crops. During this period there is little loss of water in the form of evaporation and transpiration from the unshaded portion whereas it occurs considerably in surface or sprinkler irrigation. Thus, water requirement in crops in conventional method includes the non-beneficial evaporation or transpiration from the unshaded or uncovered areas in the field. This is taken into account in calculating the water requirement of crop in drip irrigation and is modified by introducing the reduction factor called ground coverage factor (K). The method of accurate estimation of K, is still to be developed. However, the following relationships may be used for approximate estimation in which the ground cover, GC, is the fraction of the total surface area actually covered by the foliage of the plants when viewed from directly above (FAO, 1980).

### **(i) Keller and Karmeli (1974):**

$K = \frac{GC}{0.85}(1) \text{ or } 1$ , whichever is the smallest

### **(ii) Freeman and Gazzoli:**

$K, GC (1-GC)$

### **(iii) Decroix :**

$K=(0.10+ GC) \text{ or } 1$ , whichever is the smallest (3)

**The value of 0.10 includes the oasis effect, which is very important when the coverage is small.**

With the consideration of above terms and relationships, the water requirement of crop in drip



irrigation is:

$$ET_{crop} = K_p \times K_c \times K_r \times E_{pan} \quad (4)$$

We know the pan evaporation ( $E_p$ ) is very close to  $E_{To}$ , therefore  $E_T$ , often estimated by a multiplication factor called pan factor ( $K_p$ ) to ( $E_{pan}$ ). Therefore, the equation (4) becomes,

$$ET_{crop} = K_p \times K_c \times K_r \times E_{pan}. \quad (5)$$

**Problem 1:** The following are the pan evaporations ( $E_{pan}$ ) reference crop evapotranspirations ( $E_o$ ) and crop co-efficients ( $K_c$ ) of an arbitrary location and crop

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov	Dec
<b>Epan mm/day</b>	2.5	2.6	4.1	4.3	5.2	5.2	5.2	4.9	4.8	3.5	2.8	2.7
<b>Eo mm/day</b>	1.75	1.90	3.0	3.25	4.1	4.2	<b>3.9</b>	<b>3.7</b>	3.3	2.8	1.9	1.8
<b>kc</b>	0.6	0.6	0.7	0.75	0.8	0.8	0.9	0.9	0.8	0.7	0.6	0.6

### For the month of January

Determine the  $K_p$  values and water requirement of crop ( $E_{Top}$ ) at different months. Assume 45 % ground coverage from January to March and 60 % for the remaining months.

**Solution:** Using Decroix assumption,

$$K_p = 0.1 + GC$$

$$= 0.1 + 0.45$$

$$= 0.55, \text{ when GC is 45\%}$$

and

$$K_p = 0.1 + 0.6 = 0.7, \text{ when GC is 60 \%}$$

$$ET_p \text{ in any month} = K_p \times K_c \times K_r \times E_{T \text{ pan}}$$

For the month of January  $K_p = E_{To}/E_{pan} = 1.75/2.5 = 0.7$

$E_{Tcrop} = 0.7 \times 0.6 \times 0.55 \times 2.5 = 0.58 \text{ mm/day}$

**Problem 2.** The following information were obtained in a research of papaya cultivation under drip irrigation at Gayeshpur, West Bengal.

The daily requirement of a plant was determined by,

$V = E_{pan} \times K_p \times K_c \times A$

where, V = volume of water applied to each plant, l/day

$E_{pan}$  pan evaporation x 1.0, 0.8 and 0.6 at the irrigation level of 11, 12 and 13. respectively.

K Crop factor (assumed 0.8, 1.0 and 1.2 at 4-6, 7-9 and 10-12 months respectively of the crop age)

$K_c$ , pan factor 0.8

A area under a plant - 2 m x 2m

Yield 36225, 40200, 38550 and 31200 kg/ha for I, 12 and conventional method of irrigation respectively.

- A. Determine the volume of water applied at each plant at different irrigation levels for a pan evaporation of 5mm in a day at 5th month of crop age.
- B. If the cumulative pan evaporation (CPE) during the period except in the rainy days for which irrigation was required was 240 mm, find the total depth of water applied in each irrigation level.
- C. Determine the irrigation water use efficiency in different irrigation treatment and per cent increase in yield over conventional method.

**Solution:**

(a)  $V = E_{pan} \times K_p \times K_c \times A$

$I_1 = 5 \text{ mm} \times 1.0 \times 0.8 \times 0.8 \times 4 \text{ m}^2$

$5/1000 \times 4 = 0.002 \text{ m}^2 = 12.8 \text{ l/day}$

$I_2 = 5 \text{ mm} \times 0.8 \times 0.8 \times 0.8 \times 4 \text{ m}^2 = 10.24 \text{ l/day}$

$I_3 = 5 \text{ mm} \times 0.6 \times 0.8 \times 0.8 \times 4 \text{ m}^2 = 7.68 \text{ l/day}$

(b) Depth of water applied at any irrigated level,

$$I = Epan \times Kp \times K$$

The crop coefficient is taken 1.0 as the average of the crop coefficients of 0.8, 1.0 and 1.2 during the period. Therefore,

$$I_1 = 240 \text{ mm} \times 1.0 \times 0.8 \times 1.0$$

$$= 19.2 \text{ cm}$$

$$I_2 = 240 \text{ mm} \times 0.80 \times 0.8 \times 1.0$$

$$= 15.36 \text{ cm}$$

$$I_3 = 240 \text{ mm} \times 0.6 \times 0.8 \times 1.0$$

$$= 11.52 \text{ cm}$$

(c) Irrigation water use efficiency (WUE) at irrigation level,

$$I_1 = \frac{\text{Yield/ha}}{\text{depth of water applied}}$$
$$= \frac{36,225 \text{ kg/ha}}{19.2 \text{ CM}}$$
$$= 1886.72 \text{ kg/ha - cm}$$

$$I_2 = \frac{40,200}{15.36}$$

$$= 2617.19 \text{ kg/ha - cm}$$

$$I_3 = \frac{38,550}{11.52} = 3346.35 \text{ kg/ha - cm}$$

WUE in conventional method =  $31200/24 = 1300 \text{ kg/ha}$

$$I_1 = \frac{36225 - 31200}{31200} \times 100$$

$$= 16.11$$

$$I_2 = \frac{40200 - 31200}{31200} * 100 = 28.85$$

$$I_3 = \frac{38550 - 31200}{31200} * 100 = 23.56$$

Irrigation Interval: Time between the start of successive field irrigation application on the same field, in days.

**Available soil moisture (ASM):**

The difference in moisture content of the soil between field capacity (FC) and permanent wilting point (PWP) is termed the available moisture:

$$ASM=FC-PWP$$

Generally, fines the soil texture, greater the available moisture holding capacity. Approximate available moisture holding capacity of different soil textural classes

<b>Soil texture</b>	<b>Available moisture holding capacity (per cent)</b>
Coarse, fine and loamy sands	6-10
Coarse, fine and loamy sands	10-14
Very fine sandy and silt loam	12-19
Clay and silty clay loam	14-20
Sandy and silty clays and clays	13-20

**Practical significance**

**Conclusion**

Signature of Faculty In-charge

## Experiment No.13

Date-----

### Measurement of irrigation water by volume and velocity-area method and measurement of irrigation water by measuring devices

#### Aim

To study about different water measuring devices and irrigation water

Irrigation water is an expensive and limiting unit of crop production and therefore, proper quantity should be applied to a crop as per edaphic conditions. Excess supply of irrigation water is as harmful as water stress for crop growth. Therefore, effort should be made to apply the right amount of water as and when required. This is only possible by application of measured amount of irrigation water.

#### Objectives

1. To know the exact area that can be irrigated with a particular volume of water.
2. To avoid over and under irrigation.
3. To economize the use of irrigation water.
4. To save the crop from excess water application.
5. The excess water application leads to deep percolation losses and leaching of nutrients.
6. To save the crops and soil from the ill effects of excess water application (poor drainage situation).

#### Hectometer

Hectometer is the volume of water necessary to cover an area of hectare to a depth of one meter. Generally, two situations occur in irrigation water management:

- (i) Measurement of flow through open channels (Velocity and area method).

(ii) Measurement of flow through pipes (Direct discharge method).

### **Velocity and area method**

In this method the velocity of water flow in channel is measured and water discharge is calculated by the formula given below:

$$Q = A \times V$$

Where, Q Discharge of water,

A=Cross section of the flow area,

V=Velocity of flow of water.

### **This includes the following method**

(a) Float method: In this method a straight section of irrigation channel (25-50 Mt. Long) is selected and a light floating body is allowed to float along with water and the time taken to cover the distance is recorded. An average velocity of channel often takes to be 0.8 the surface velocity as obtained with the float. Though the factors may be reduced if the channel is narrow, irregular and rough. It is a cheapest and simplest method of water discharge measurement but not so accurate.

### **(b) Current meter**

Current meters are used for measuring the velocity in channels, streams and long rivers. The water velocity is measured by noting the time taken for certain revolutions and using the meter calibration curve that relates the meter speed caused due to water flowing velocity. Water meters show the discharge of water directly in gallons or liters. They are the most reliable and standard devices for measuring discharge of water. (c) Tracer method

The principle involved in this method is that a substance which dissolve in water but does not react with it, is introduced into the flow, and its concentration is measured at two points. Assuming that the substance completely mixes with water and there is no loss of water between

the points of mixing and measurement. In this method common salt or dye (salt dilution method) or radioisotopes are mixed with water and salt concentration or isotopes count is measured at downstream.

## Materials required

- Weirs
- Orifices
- Scale
- Spade

## Introduction

Measurement of irrigation stream is essential for the studies on soil-water-plant relations and for judicious management of water on the farm to obtain high efficiency in irrigation. Irrigation water is generally measured under two conditions:

- i) At rest: Measured in units of volume such as liter, cubic meter, hectare centimeter (ha cm) and hectare meter (ha-m)
- ii) In motion: Expressed in rate of flow units such as litres per second, liters per hour, cubic meters per second, hectare centimeters per hour and hectare meters per day.

## Units of volume:

- i) **Liter:** It is a volume equal to 1/1000 cubic meter ( $1000 \text{ cm}^3$ )
- ii) **Cubic-meter:** It is a volume to that of a 1 meter long, 1 meter wide and 1 meter deep container (1 cubic meter = 1000 liters)
- iii) **Hectare centimeter (ha cm):** It is a volume of water necessary to cover an area of 1 hectare to a depth of 1 cm (100 cubic meters = 100,000 liters)
- iv) **Hectare meter (ha m):** A volume necessary to cover an area of 1 hectare to a depth of 1 meter (10,000 cubic meters = 10 million liters)

## Units of flow:

- i) **Litre per second:** A continuous flow amounting to 1 litre passing through a point each second. It is generally used to denote the discharge of a pump, small stream or pipe line.
- ii) **Cubic- metre pre second:** A flow of water equivalent to a stream 1 metre wide and 1 m deep, flowing at a velocity of 1 metre per second.

## **Working principle**

The velocity of water in a stream or river may be measured directly with a current meter and the discharge estimated by multiplying the mean velocity of water by the area of cross section of the stream. When mean velocity of a stream is determined with current meter the cross section of flow is divided into a number of sub-areas and separate measurements are made for each sub area. It has been found that the average of readings taken at 0.2 and 0.8 of the depth below the surface is an accurate estimate of the mean velocity in a vertical plane

## **Procedure**

### **Measuring structures**

In farm irrigation practice, the most commonly used devices for measuring water are weirs, parshall flumes, orifices, siphons and water meters. In these devices the rate of flow is measured directly by making a reading on a scale which is a part of the instrument and computing the discharge rate from standard formula. The discharge rate can also be obtained from ready reckoners prepared for the instrument.

#### **A. Weirs**

A weir is a notch of regular form through which water may flow. Notch may be rectangular, trapezoidal or triangular ( $90^{\circ}$ -V). Rectangular and  $90^{\circ}$  V-notch weirs are commonly used on the farm.

##### **i) Rectangular weir**

It is used to measure comparatively large discharges. The length of a rectangular weir may be equal to the width of the channel (suppressed rectangular weir) or less (contracted rectangular weir). The discharge through a rectangular weir may be calculated by the following equation:



Suppressed rectangular weir:

$$Q = 0.0184 LH^{3/2}$$

Where, Q = Discharge (litres/sec.)

L = Length of crest (cm)

H = Head over the crest (cm)

**Contracted rectangular weir:**

$$Q = 0.0184 (L-0.2H) H^{3/2}$$

Where, Q = Discharge (litres/sec.)

L = Length of crest (cm)

H = Head over the crest (cm)

**ii) Trapezoidal or cipolletti weir**

The discharge of water through this type of weir may be computed by the formula given below:

$$Q = 0.0186 LH^{3/2}$$

Where, Q = Discharge (litres/sec.)

L = Length of crest (cm)

H = Head over the crest (cm)

**iii) 90° V-Notch weir**

It is commonly used to measure small and medium sized streams. The advantage of the V-notch weir is its ability to measure small flow accurately. The discharge through a 90° V-notch weir may be computed by the following formula:

$$Q = 0.0138 H^{5/2}$$

Where, Q = Discharge (litres/sec.)

H = Head over the crest (cm)

**B. Orifices**

Orifice plates can be used to measure comparatively small streams like flow into border strips, furrows or check basins. It consists of iron, steel or aluminium plate that contains accurately circular opening usually ranging from 2.5 cm to 7.5 cm in diameter. A plastic scale may be fixed directly on the upstream face of the orifice plate with its zero reading coinciding with center of the orifice.

The discharge through an orifice is calculated by the formula:

$$Q = 0.61 \times 10^{-3} \times a \sqrt{2gH}$$

Where, Q = Discharge through orifice, liters /sec.

a = Area of cross section of the orifice, cm<sup>2</sup>

g = Acceleration due to gravity, cm /sec<sup>2</sup> (981 cm/sec<sup>2</sup>)

H = Depth of water over the center of the orifice, cm.

### **C. Parshall flume**

Parshall has developed a device to measure the flow in which the discharge rate of water is obtained by measuring the drop in head. It is a self-cleaning device. It is suitable for measuring a wide range of stream sizes, from a few litres/sec. to several cubic metres/sec. It can be used in relatively shallow channels like irrigation furrows. It may also be used to measure the flow of large streams. The Parshall flume consists of a metal or concrete channel structure having three principal sections:

1. Converging section at upstream end
2. Constricted section or throat.
3. Diverging or expanding section at downward.

The size of the flume is determined by the width of the throat of the flume. The flumes of about 7.5, 15.0 and 22.5 cm sizes are used in field measurements.

### **Discharge through the flume can occur under the following conditions:**

1. **Free flow:** When elevation of the water surface near the downstream end of the throat section is not high enough to cause any retardation of the flow due to a back flow of water is termed as free flow. Under this condition, only one measurement of the head or

water level ( $H_a$ ) in the converging section is required to estimate the rate of flow.

2. **Submerged flow:** When the elevation of the water surface downstream from the flume is high enough to retard the rate of discharge, the flow is said to be submerged flow. The important point in Parshall flumes is the ratio between the reading at  $H_b$  and  $H_a$  heads. This ratio should not exceed 0.6 for 7.5, 15.0 and 22.5 cm size flumes. If the ratio exceeds 0.6, it is termed as submerged flow. To determine this ratio,  $H_a$  and  $H_b$  are provided at the upstream and downstream sections of the flume. In this case a correction is subtracted from free flow conditions to obtain the correct rate of flow.

#### D. Syphons

These are generally used to irrigate the field from canals and channels. Syphons are the pipes usually made of rubber or plastic or aluminum. Following formula can be used to measure the discharge rate of syphons:

$$Q = 0.61 \times 10^{-3} \times A \sqrt{2gh}$$

Where,  $Q$  = Discharge rate of water (l /sec.)

$g$  = Acceleration due to gravity (981 cm/ sec.<sup>2</sup>)

$h$  = Height of water (cm)

$A$  = Cross sectional area of the water in the syphon (cm<sup>2</sup>).

#### Calculation

1. Calculate the discharge rate of water of a suppressed rectangular weir 50 cm long with a head of 15 cm.

$$Q = 0.0184 LH^{3/2}$$

$$= 0.0184 \times 50 \times 15^{3/2}$$

$$= 0.0184 \times 50 \times 58.095$$

$$= 53.45 \text{ L/S}$$

2. Calculate the discharge rate of water of a contracted rectangular weir 40 cm long with a head of 10 cm?

$$Q = 0.0184 (L - 0.2H) H^{3/2}$$

3. Calculate the discharge rate of water of a 90° V-notch with a head of 12 cm.

$$Q = 0.0138 H^{5/2}$$

### **Precautions**

- From rust
- Handle properly after using it

### **Practical significance**

A weir or flumes low head dam is a barrier across the width of a river that alters the flow characteristics of water and usually results in a change in the height of the river level. There are many designs of weir, but commonly water flows freely over the top of the weir crest before

cascading down to a lower level.

The Parshall flume is an economical and accurate way of measuring the flow of water in open channels and non-full pipes. The flume was originally developed to measure surface waters, water rights apportionment, and irrigation flows, but its use has expanded to include measuring the flow of sewage (both in pipe and treatment plants), industrial discharges, and seepage from dams.

## **Conclusion**

**Signature of Faculty In-charge**



## Experiment No. 14

Date-----

### Calculation of Irrigation Efficiency

#### Aim

To study about different irrigation efficiencies parameter

#### Materials required

1. Pen
2. Pencil
3. Note book

#### Calculations on irrigation efficiencies

Irrigation efficiency indicates how efficiently the available water supply is being used, based on different methods of evaluation. The objective of efficiency concept is to show where improvements can be made, which will result in more efficient irrigation. Various efficiency terms are:

##### i) Water conveyance efficiency

This term is used to measure the efficiency of water conveyance systems associated with the canal network, water courses and field channels. It is also applicable where the water is conveyed in channels from the well to the individual fields. It is expressed as follows:

$$E_c = \frac{W_d}{W_f} \times 100$$

Where,  $E_c$  = Water conveyance efficiency, per cent

$W_d$  = Water delivered to the irrigated plot (at the field supply channel)

$W_f$  = Water diverted from the source

##### ii) Water application efficiency

After the water reaches the field supply channel, it is important to apply the water as efficiently as possible. A measure of how efficiently this is done is the water application efficiency, expressed as follows:

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

Where, Ea = Water application efficiency, per cent

Ws = Water stored in the root zone of the crop

Wd = Water diverted to the field (at the supply channel)

### iii) Water storage efficiency

The water storage efficiency refers how completely the water needed prior to irrigation has been stored in the root zone during irrigation. It is expressed as :

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

Where, Es = Water storage efficiency, per cent

Ws = Water stored in root zone during irrigation

Wn = Water needed in root zone prior to irrigation

### iv) Water distribution efficiency

Water distribution efficiency indicates the extent to which water is uniformly distributed along the run. It is expressed as:

$$Ed = 100\left(1 - \frac{y}{d}\right)$$

Where, Ed = Water distribution efficiency, per cent

d = Average depth of water stored along the run during the irrigation

y = Average numerical deviation from d

### v) Water use efficiency

It refers to the amount of marketable end product obtained per unit of water used by the crop.

$$WUE \text{ (kg ha}^{-1} \text{ mm}^{-1}\text{)} = \frac{\text{Total economic yield (kg ha}^{-1}\text{)}}{\text{Total consumptive use (mm)}}$$



(i) **Crop water use efficiency:** It is the ratio of crop yield (y) to the amount of water depleted by the crop in the process of evapotranspiration (ET).

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

(ii) **Field water use efficiency:** It is the ratio of crop yield (y) to the total amount of water used in the field (WR)

$$\text{Field water use efficiency} = \frac{Y}{WR}$$

### vi) **Project efficiency**

Project efficiency indicates the effective use of the irrigation water source in crop production. It is the percentage of irrigation water that is stored in the soil and is available for consumptive use by crops. When the delivered water is measured at the farm head gate or well, it is called farm irrigation efficiency, when measured in the field, it is designated as field irrigation efficiency, and when measured at the point of diversion from the canal or the main source of supply it may be called project efficiency.

### vii) **Operational efficiency**

Operational efficiency is the ratio of actual project efficiency compared to the operational efficiency of an ideally designed and managed system using the same irrigation method and facilities. Low operational efficiency indicates management or system design problems, or both.

### viii) **Economic (irrigation) efficiency**

Economic efficiency is the ratio of the total production (net or gross profit) attained with the operating irrigation system, compared to the total production expected under ideal conditions. This parameter is a measure of the overall efficiency, because it relates the final output to input.

### **Significance of irrigation efficiencies**

A low value of any of the irrigation efficiencies in general implies that the land, water and the crops are not being managed properly. A low conveyance efficiency implies that much of the

water released from the source is lost in transit from source to the field. A low application efficiency means wastage of water in the form of deep percolation or runoff losses. A poor storage efficiency means water has been applied inadequately. A poor distribution efficiency results due to uneven land surface. There are low patches where water will penetrate more and there are high patches where water cannot reach. A low water use efficiency also results due to over application of water or inability of the crops to utilize the applied water due to poor vegetative growth or adverse chemical properties of root zone soil and water. The net effects of poor irrigation efficiencies are crop loss and wastage of water and nutrients.

**Problem 1:**

A stream of 135 liters/sec. was diverted from a canal and 100 litres /sec. were delivered to the field. An area of 1.6 ha was irrigated in 8 hours. The effective depth of root zone was 1.8 m. The run off loss in the field was 432 m<sup>3</sup>. The depth of water penetration varied linearly from 1.8 m at the head end of the field to 1.2 m at the tail end. Available moisture holding capacity of the soil is 20 cm/m depth of soil. Calculate water conveyance efficiency, water application efficiency, water storage efficiency and water distribution efficiency, irrigation was started at a moisture depletion level of 50 per cent of the available moisture.

**Solution**

$$W_f$$

(i) **Water conveyance efficiency,  $E_c = \frac{W_d}{W_s} \times 100$**

$$W_d$$

$$100$$

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

$$135$$

$$W_s$$

(ii) **Water application efficiency,  $E_a = \frac{W_d}{W_s} \times 100$**

$$W_d$$

$$100 \times 60 \times 60 \times 8$$

Water delivered to the plot =  $\frac{100 \times 60 \times 60 \times 8}{1000} = 2880$  cu. m

$$1000$$

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

$$\text{Water application efficiency, } E_s = \frac{2448}{2880} \times 100 = 85\%$$

**Ws**

**(iii) Water storage efficiency,  $E_s = \frac{\text{Ws}}{\text{Wn}} \times 100$**

Water holding capacity of root zone = 20 x 1.8 = 36 cm

$$36 \times 50$$

Moisture required in the root zone = 36 -  $\frac{100}{100}$  = 18 cm

$$100$$

$$18 \times 1.6 \times 10,000$$

$$= \frac{2880000}{100} = 2880 \text{ cu.m}$$

$$100$$

$$2448$$

Water storage efficiency =  $\frac{2448}{2880} \times 100 = 85\%$

$$2880$$

**v) Water distribution efficiency,  $E_d = 100(1 - \frac{y}{d})$**

$$1.8 + 1.2$$

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

$$2$$

Numerical deviation from depth of penetration:

$$\text{At upper end} = 1.8 - 1.5 = 0.3$$

$$\text{At lower end} = 1.2 - 1.5 = (-0.3) = 0.3$$

$$0.3 + 0.3$$

$$\text{Average numerical deviation} = \frac{0.3 + 0.3}{2} = 0.3$$

$$E_d = 100\left(1 - \frac{0.3}{1.5}\right) = 80\%$$

### **Question**

A stream of 140 lps was diverted from a canal and 110 lps was delivered to the field. An area of 1.5 ha was irrigated in 8 hrs. The effective depth of root zone was 1.6 m and run off during irrigation was 430 m<sup>3</sup>. The depth of water penetration varied linearly from 1.6 m at head end to 1.2 m at tail end. AMHC of soil is 25 cm/m depth of soil. Irrigation was started at 50% depletion of available moisture. Calculate water conveyance, water application, water storage and water distribution efficiencies.

### **Solution:**

### **Significance of irrigation efficiencies**

A low value of any of the irrigation efficiencies in general implies that the land, water and the crops are not being managed properly. Low conveyance efficiency implies that much of the water released from the source is lost in transit from source to the field. Low application efficiency means wastage of water in the form of deep percolation or runoff losses. Poor storage efficiency means water has been applied inadequately. A poor distribution efficiency results due to uneven land surface. There are low patches where water will penetrate more and there are high

patches where water cannot reach. Low water use efficiency also results due to over application of water or inability of the crops to utilize the applied water due to poor vegetative growth or adverse chemical properties of root zone soil and water. The net effects of poor irrigation efficiencies are crop loss and wastage of water and nutrients.

## **Conclusion**

**Signature of Faculty In-charge**