PRACTICAL MANUAL

ON

PRECISE IRRIGATION

M. P. Tripathi **R. K. Sahu**
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DEPARTMENT OF SOIL AND WATER ENGINEERING
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FOREWORD

In many areas of the Chhattisgarh the amount and timing of rainfall are not adequate to meet the moisture requirement of crops therefore precise irrigation is essential to raise the crops to meet the requirement and to enhance economy of the State. Practical manual in its present form will be an effective aid for students as well as agriculturists

The manual contains easy and appropriate information regarding irrigation and water management. This publication will also help the students to understand the meaning of precise irrigation.I compliment the authors for their efforts.

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Section 1

Soil Moisture Measurement

Soil acts as a water reservoir for plants. A soil particle holds water on its surface in a form of thin film with a certain force. Space in between soil particles known as pore space, contains both air and water in varying proportions. Immediately on irrigation, when the soil is completely saturated all the pore space is occupied by water. Due to loss of soil moisture because of deep percolation, evaporation and transpiration, the percentage of air goes on increasing in the pore space. As soils are normally moistened with water, the terms soil moisture and soil water are used generally as synonyms or interchangeably.

Soil moisture is expressed as a percentage on oven dry basis either on weight basis (Pw) or on volume basis (Pv) *e.g.*, when a soil is stated to contain 10 per cent moisture on dry weight basis, it means 100 g of dry soil hold 10 g of water. When expressed on volume basis, it means 100 cubic cm of soil hold 10 cubic cm of water. The moisture percentage is generally expressed on weight basis. Unless should otherwise.

The moisture percentage on weight basis (Pw) can be converted in moisture percentage on volume (Pv) basis if apparent specific gravity (As) of soil is known. Apparent specific gravity of soil can be calculated using following formula:

$$\text{Apparent Specific Gravity} = \frac{\text{Bulk density of soil}}{\text{Density of water}} \qquad \dots (1)$$

$$\text{Bulk density of soil} = \frac{\text{Oven dry weight of soil (g)}}{\text{Volume of soil (cm}^3\text{)}} \quad \text{... (2)}$$

The moisture percentage as volume basis can be calculated as follows:

$$Pv = \frac{\text{Vol. of water}}{\text{Vol. of soil}} = \frac{\text{Weight of water}}{\text{Density of water}} \div \frac{\text{Weight of soil}}{\text{Bulk density of soil}}$$

$$Pv = \frac{\text{Weight of water}}{\text{Density of water}} \times \frac{\text{Bulk density of soil}}{\text{Weight of soil}}$$

$$Pv = \frac{\text{Weight of water}}{\text{Weight of soil}} \times \frac{\text{Bulk density of soil}}{\text{Density of water}} = Pw \times As$$

$$Pv = PwXAs \quad \text{...(3)}$$

Sampling for soil moisture measurement

Importance

1. Soil moisture measurements are important for suitable scheduling of irrigations and estimation the depth of water to be applied in each irrigation.
2. Measurement of changes in soil moisture storage with time are important in estimating evopotranspiration (ET)
3. To find out the moisture status in crop root zone for ascertaining its adequacy irrelation to growth and development of crop.

Materials

A 2.5 cm screw auger, tube auger, post hole auger, core sampler, aluminium water tight moisture boxes (6 cm diameter and 5 cm height), metal rod, gunny sack, plastic sheet and wooden stakes.

Procedure

Select a leveled spot in middle of a plot and mark its centre with a stake. Sample within a radius of about 50 cm from the centre to study the continuous soil moisture changes. If sampling spots are choosen randomly in the entire field, results are erratic.

Draw the sample with an auger from the desired depth and remove it from the grooves of the auger on a plastic sheet. Select about 50 gm of soil and transfer it to the moisture box quickly. Considerable errors can occur by evaporation of moisture if the sample remains exposed to atmosphere for a long time. Close the bore with soil and tamp of with a metal rod. The hole after filling must be at the same level as the rest of the soil surface. Avoid sub-sampling as it furnishes lower moisture content readings due to loss of moisture during the process. Similarly avoid contamination of the material from different layers during insertion of withdrawal of the auger.

While sampling in a crop, select the spot in a row between the two plants. During young stage, take the sample as near the plant as possible without disturbing it, say about 10 cm away form it. As the crop grows, samples can be taken towards the point midway between the two rows.

If the soil is dry and the sample is likely to spill out, use a hammer tube auger or jack puller hammer auger.

Measurement of soil moisture content by different methods

Gravimetric method

Principle

The pre-weight moist soil sample is dried in the oven at 105^{0}C to evaporate entire moisture present in soil sample and its amount is known by difference in weight of moist and dry soil samples.

Instrument/equipments

Balance, hot air oven, soil sampling auger/tube, soil sample container, spatula, polythene sheet

Procedure

- Collect soil samples from different depths of the crop root zone.
- Properly mix the soil samples on a polythelene sheet and take about 40 to 50 g in numbered sample container and cover it.
- Uncover the sample container and weigh the sample with container.
- Put in hot air oven with temperature adjusted at 105^{0}C for 8-10 hrs.
- After drying overnight, take out the containers with sample, cool it and weigh again, put the samples in oven and again take the weight. Repeat drying till constant dry weight is obtained.
- Calculate the moisture percentage by using the Procedure described:

Observations and calculations of soil moisture by oven drying method

Field No____________________ Date ________________________

Crop _______________________ Time________________________

Observer/sample

Collector ___________________

Soil depth	Soil layer thickness cm, d	Can No.	Can wt.	Wet wt. with can	Dry wt. with can	Dry wt. of soil	Wt. of moisture	Moisture % (by wt $\frac{W_1 - W_2}{W_2 - C} \times 100$	B.D. g/cm^3.	Soil moisture (in mm.) $\frac{M \times b \times d}{100}$
(mm)	(d)	-	(c)	(W_1)	(W_2)	($W_2 - C$)	($W_1 - W_2$)	(M)	(b)	(mm)

Measurement of soil moisture content by alcohol (Spirit) burning method

Principle

The soil moisture is rapidly evaporated by adding alcohol to soil and igniting it. The water content is found out on dry weight basis within a very short time.

Instrument, equipment and materials

Aluminium can, silica disk, alcohol or spirit, balance, wire screen with asbestos pad, tripod stand

Procedure

- Take about 10 to 20 g moist soil sample and spread on wire screen placed over a small tripod stand resting on some dish
- Add alcohol or spirit by a dropper till the soil is saturated. Generally 0.5 g alcohol is required each gram of soil
- Ignite the alcohol and wait till the burning is over
- Allow the sample to cool and weigh it
- The above process of drying of the sample is repeated till constant dry weight of soil sample is attained
- Calculate the moisture content using the procedure given above

Measurement of soil moisture content by neutron scattering techniques

Principle

Fast neturons emitted from americium-berrillium source have energies in the range of 5-10 Mev. When a fast neutron collides head-on with hydrogen atom, it imparts whole of its energy to the hydrogen atom and slows down with energy of the order of even less than 1 ev. The slowed down neutron is called thermal neutron. Water being dominated by hydrogen atoms has potential of slowing down fast neutrons. The fraction of neutrons slowed down depends upon the dominance of hydrogen nuclei, which can assess the soil water content in the sample. Hydrogen dominance in the soil is mainly attributed to the water content.

Instruments, equipments and materials

Neutron moisture meter, aluminium access tubes, balance, oven, aluminium boxes and screw auger/tube auger.

Procedure

- Install the aluminium access tube of specific diameter with closed bottom upto the crop rooting depth. For this a hole of diameter equal to outer diameter of the access tube is made in the field. The access tube is inserted in it, keeping 20-30 cm above the ground. Generally a two meter length access tube is installed. The gap between outer circumference of the tube and inner wall of the hole is filled with soil slurry in order to ensure proper contact of the access tube with the field soil. Cover the opening of the tube with a rubber stopper.

- Before taking actual observation for the soil moisture, take standard count (N_s) by placing the neutron moisture meter on the top of the open access tube, keeping the instrument in ON position and timer at 4 minutes mark.
- Lower down the probe into the access tube until the desired soil depth, put the instrument on measurement mode and the timer at the desired option of 4 minutes/1 minute/30 seconds. After this time, record the measured count (N_m). Continue the same process to measure the count at lower depths.
- Find out soil moisture against the count ratio (N_m/N_s) from the calibration curve prepared for this soil by measuring various count ratios and corresponding water content values at different soil depths. Obtain directly the soil moisture from the instrument in case there is builtin microprocessor in the unit.

Feel and appearance method for soil moisture determination

A common method in use is the feel and appearance method where the amount of moisture present is estimated. When the field capacity of the soil is known, the amount of moisture needed is then easy to calculate.

Although gauging moisture conditions by feel and appearance is not the most accurate method, with experience and judgment the irrigator should be able to estimate the moisture level within 10 to 15%. A guideline is enclosed to find out soil moisture and irrigation needed with the help of feel and appearance method in different soil types.

Observations and calculations for soil moisture by Neutron Moisture Meter

Field No. Date

Crop Time

Observer

Standard count (N_s) I________ II________ Av________					
Soil depth cm (d)	Layer Thickness cm	Measurement Count (N_m)	Count ratio (N_m/N_s)	Soil moisture % by volume	Soil moisture* Mm $\frac{a \times d}{100}$

*To be obtained from appropriate calibration curve of from the instrument with micro processor

Precautions

- Do not monitor soil moisture by this technique for first 20 cm depth as the worker is likely to be exposed to neutron flux which to be hazardous to health
- Recharge the instrument periodically to maintain the battery life
- Always keep the probe with in the shield when the instrument is not in use
- The worker must wear radiosafety badge and undergo periodical checkups for radioactivity hazard.

Determination of Bulk Density or Apparent Specific Gravity of Soil

Bulk density of soil (b) is the dry mass, per unit volume of a given soil in its natural condition and is given by:

$$p_b = \frac{M_s}{V_t} \qquad ...(4)$$

in which Ms is the mass of dry soil solid (g), V_t is the total or bulk volume of soil (cm^3). p_b has unit of g./m^3. Since the total volume includes the actual volume occupied by the soil solids as well as pore volume. Bulk density will, therefore, vary not only with the actual density of the solids, but, also more importantly with the packing of the soil particles. Hence, a given soil can have widely varying bulk density values depending upon the state and of compaction or aggregation.

The bulk density of fine textured mineral soils may range from about 1.0 to 1.3 g./cm^3 and that of coarse textured soils from 1.4 to 1.7 g./cm^3. Tillage operations that loosen soils temporarily lower bulk density, while compaction raises bulk density. Natural soil forming processes that increase aggregation reduce bulk density.

Importance

Bulk density of a soil is required to be known the following:

1. For determining the degree of compactness as a measure of soil structure.
2. To calculate soil pore space (%) for the following formula:

$$\text{Porosity or \% pore space} = 100\ \frac{\text{B.D.}}{\text{P.D.}} \times 100 \text{ or } \left(1 - \frac{\text{B.D.}}{\text{P.D.}}\right) \times 100 \quad ...(5)$$

3. As an indicator of aeration status (for which the water content is also required)
4. To convert soil and nutrient values from the gravimetric to volumetric basis, and
5. To provide information on the environment, available to many soil micro-organisms, which live within them.

Bulk density is generally obtained by removing a block of soil from the site under study, allowing no compaction of crumbling. This can be accomplished by using any method that forces a straight-sided container of known volume into the soil without altering the area to be sampled. The container is then dug out, excess soil is trimmed away, dried and weighed and p_b is calculated. This involves inserting a core of known dimensions into the soil and extracting a sample of known volume. In the absence of a core sampler- a rigid shallow tin (metallic) can also be used in field situations.

Equipment and materials required

Balance, oven, core sampler assembly with cores, spatula, vernier calipers, moisture can boxes, scale.

Procedure

1. The core sampler is assembled with the core placed inside after a through cleaning.
2. For surface samples, prepare the soil surface by removing vegetation and loose soil and smoothen the soil surface. For samples from lower depths, excavate the soil to the appropriate depth. (Layerwise bulk density samples are best taken when the soil profile pit is being dug routinely).
3. Drive the core sampler into the soil with the hammer provided.
4. Carefully dig out/ remove the core sampler and dismantle the assembly and trim out excess soil from the two ends of the core with a spatula.
5. Transfer the core into a container or remove the soil from the core into a labeled sample bag for transporting of the laboratory.
6. Soil samples are dried in a hot air oven at 105^{0}C till constant mass is attained. The dried soil samples are weighed and their masses are recorded on the observation sheet.
7. The diameter and length of the core are also measured using calipers for calculating the volume of the core. The bulk density is then calculated by the formula given above.

Determination of bulk density of soil

Name:
Sample location:
Soil description:

Depth of sample (cm)	Sample No.	Sample volume			Can No.	Sample Mass			Bulk density $\rho_b = M_s/V_t$ g/Cm^3
		Inner dia (cm)	Sample length (cm)	Sample volume V_t (cm^3)		Can and volume, mass (g)	Can Mass (g)	Sample Mass, Ms (g)	
0-15 15-30 30-60 60-90 90-120 120-150									

Determination of Particle Density or True Density of soil

Introduction

Particle density (p_s) is the mass (weight) of a unit volume of soil clods and is expressed in metric units in grams per cubic centimeter. The particle density for most mineral soil varies from 2.60 to 2.75 g/cm$^{-3,}$ as the bulk of the soil consists of quartz, feldspars and colloidal silicates. However, values exceeding 2.75 are met in cases where heavy mineral particles, *viz.*, magnetite, garnet, epidote, zircon, tourmaline, and hornblende are present in unusual quantities. Solids containing high amounts of organic matter will have particle densities around 2.4, as one cubic centimeter weighs less than an equal volume of mineral solids. For this reason, subsurface soils have higher particle density than surface soils. Fineness as well as arrangement of soil particles does not affect particle density.

Importance

Knowledge of particle density is important in volume relationship of the soil, *viz.*, porosity, bulk density, and void ratio. Particle density is used in calculating the rattling velocity of particles of different sizes, during particles size analysis.

Method of Determination

Particle density determination is based on the measurements of weight of solids and their volume. The weight of solids is obtained by weighing a sample of oven-dried soil. The volume of solids is determined by immersion. The method outlined here is the "Pycnometer method".

Principle

A given amount of dry soil when, immersed in a definite volume of water, expels air, and results in the displacement of equal volume of water. The volume of soil particle is determined by measuring the volume of water displaced in the pycnometer bottle.

Mathematically,

$$W_w = W_{pw} + W_s - W_{psw}$$

But, $W_w = V_s P_w$

And, $V_s = \frac{W_s}{P_s}$

Thus, $p_s = \frac{W_s P_w}{W_w}$

Therefore, $P_s = \frac{W_s}{W_{pw} + W_s - W_{psw}}$ gm.cm^{-3}. ...(6)

Apparatus

A pycnometer; a pipette (20 ml cap); an analytical balance; a hot plate or water bath; filter papers.

Procedure

- Fill up a clean, dry pycnometer with deaerated water. Note its temperature.

- Replace the stopper and wipe out the surface of the pycnometer and weigh it.
- Empty it and put into it 10g oven-dried soil (in the absence of oven-dried soil, a duplicate sample may be placed in the oven for the determination of its water content).
- When the bottle is half filled, using the pipette, wash soil particles sticking to the inner side of the neck.
- Boil the contents to remove the entrapped air (leave the soil overnight in the case of heavy clay, so that all soil pores become water-saturated).
- Cool the contents to room temperature and fill the pycnometer with dearated water.
- Insert the stopper, wipe the surface of the pycnometer, dry and weight it.

Observation and calculation

- Wt. of water-filled pycnometer = W_{pw} g
- Wt. of dry soil = 10 g
- Wt. of pycnometer + water + soil = W_{psw} g
- Volume of water displaced = $(W_{pw} + 10 - W_{psw})$ cm^3

  (volume of soil solids)

- Particle density of soil = $\frac{10}{W_{pw} + 10 - W_{psw}}$ g cm^3 ....(7)

Determination of moisture equivalent

The term moisture equivalent was introduced by Briggs and McLane in 1907. They defined it as the amount of moisture percentage on oven-dry basis held by a soil one cm thick when subject to 2440 r. p. m. for 30 minutes in a centrifuge which corresponds to 1000 times the gravitational force. Veihmeyer later conducted several trials and redefined it to minimize variations in the determinations by different workers. According to the modified technique, the moisture equivalent is the amount of moisture in percentage on oven-dry basis held by 30 g. of air dry soil when subject to 1000 times the gravitational force in centrifuge for 30 minutes.

The term field capacity which was introduced later is more commonly used in soil water and plant relationships. In sandy soils, the field capacity exceeds the moisture equivalent. In very clayey soils, the field capacity is generally lower than the moisture equivalent. In medium soils with field capacity ranging from 14% to 35%, the values of field capacity and moisture equivalent are nearly equal. In soils with low permeability such as alkali soils, the moisture equivalent should not be determined by the centrifuge method as these remain considerably wet and do not drain adequately in 30 minutes.

Materials

Briggs and McLane centrifuge with sample cups, moisture cans, physical balance, drying oven, spatula, water-trough & What man No. 2 filter paper.

Procedure

Place a Whatman No. 2 filter paper on the wire gauged bottom of the brass cups supplied with the centrifuge. Weigh 30 gm. of air dry soil passed through a 2 mm sieve in duplicate samples and place them in the brass cups. Place the cups in a water trough over night. Wipe out the moisture, cover them with their lids and transfer them to the centrifuge arranging them opposite each other for correct balancing. The rotating head and close the centrifuge. Switch on the power and increase the speed gradually to 2440 r.p.m. in 3 minutes. After half an hour reduce the speed gradually in 3 minutes and switch off the power. Transfer the soil samples in moisture cans and determine their moisture content as usual which represents the moisture equivalent.

Soil Water Retention Characteristics

Soil is a porous medium having pores varying widely in their sizes. Due to the geometry of the pore spaces between the soil particles and the nature of the surface, soil has the capacity to hold water. This property of soil enable the soil to retain precipitation or irrigation water in the root zone to be used by plants over time. The amount of water held depends upon the porosity and pore size distribution and the capillary pressure of water in the soil. This relationship between the amount of water held in a soil (soil water content expressed in % by wt. or % by vol.) and the force by which it is held (capillary pressure of suction or tension referred to as soil water/matric potential/tension expressed in bars of kPa or MPa) is depicted in the form of a curve commonly referred to as the soil water characteristic or soil moisture release curve or soil moisture retention curve. This curve provides information about the amount of water that would be released when tension increases (or soil matric potential decreases) from a lower to higher value.

The curve is typically plotted between saturation and permanent wilting point and can be subdivided into two regions. The region between saturation to one bar is more a function of soil water structure and, therefore, undisturbed samples must be used to estimate this portion of the curve. The portion between one bar to 15 bars is a function of the specific area of the soil i.e. soil texture, and, therefore disturbed samples can be used for the estimation of this part of the retention curve.

Determination of Field Capacity (FC) and Permanent Wilting Point (PWP) of soils

Field Capacity (FC) is the term used to describe the maximum amount of water that a soil will retain after allowing free drainage to occur. It does not generally correspond to a fixed soil water suction (or potential) which varies from 1/10 bar (10 kPa) for coarse textured soils to 1/3 bar (33 kPa) for fine textured soils. Since FC values are dependent on the structure, they are best estimated in the field. Even undisturbed cores are not truly representative of the field values.

Field Estimation of FC

Equipment and Materials required

Balance, oven, plastic, sheet, straw mulch, source of water, soil sampling auger, aluminium (moisture) cans.

Procedure

- A representative bare plot, eg. 3m x 3m, is leveled properly and bunded (30 cm high).
- Water is continuously ponded on the bare plot till the profile is fully wetted upto at least 30 cm below the proposed sampling depth. The sampling depth must extend upto the root zone of the crops to be cultivated in the area.
- Immediately after ponding is over, the plot for several days is covered with a polythene sheet to prevent evaporation. Mulch is also applied to avoid any excessive heating of the soil surface.
- Soil water content samples are taken at various depths every 24 hours until the moisture content as successive samplings

agree to within 1 per cent (Data is recorded on the observation sheet provided).

- A curve is plotted of the moisture content values against time. The moisture content around which the curve flattens represents the Field Capacity value. (if frequent samplings are not possible, the sampling is done 48 hours after ponding ceases and the moisture content recorded as field capacity).

Permanent Wilting Point (PWP) is the soil water content at which sunflower or some other indicator plants wilt permanently when placed in a humid environment.

Equipment and Materials required

Balance, oven, Sunflower seedlings, bell jar pot.

Procedure:

- Sunflower seedlings are grown in a plot containing soil of which the PWP is to be determined for three to four weeks with regular waterings.
- After three to four weeks, feather waterings of the seedling is stopped. This is continued till the plant shows wilting symptoms (dropping of leaves).
- The wilted plant is then covered with a transparent bell jar with a bowl of water inside to create a humid environment inside the jar. The plant more often than not recovers. This is called Temporary Wilting.
- The bell jar is removed and the plant is allowed to grow but no water is given to it. After some time the plant shows wilting symptoms again.

- The previous two steps are repeated until the plant does not recover even when placed inside the jar in a humid environment.
- At this stage the soil is sampled and its moisture content determined gravimetrically. This is termed as the Permanent Wilting Point (PWP) of the soil.

Laboratory determination of PWP and FC

Field Capacity and Permanent Wilting Point are generally estimated in the laboratory using either a pressure plate or a pressure membrane apparatus. A pressure plate or a pressure membrane assembly essentially consists of a chamber called the extractor in which soil samples are placed over a ceramic-plate of cellulose membrane whose outlet is connected to the atmosphere. Compressed air is then forced into the extractor either through a compressor or a cylinder containing compressed gas. Pressure is maintained at the desired level e.g. 15 bars. Till the outflow of water ceases i.e. the soil is in equilibrium with the applied pressure. The moisture content is them estimated gravimetrically.

Equipment and Materials required

Balance, oven, Pressure plate setup, ceramic plates of different ratings (1 bar, 15 bar), sampling rings (rubber), de-aired distilled water.

Pressure Plate Assembly: As far as possible, undisturbed cores should be taken for laboratory estimation of FC and PWP. For disturbed samples, soil should be air dried. pulverized and passed through 2 mm sieve. Field capacity can also be determined in the laboratory with this equipment using an applied pressure of 1/3 bar for clayey soils and 0.1 to 0.2 bar for sandy loam soils. The moisture content at an applied pressure of 15 bars is taken as the lower limit of available water and referred to as the Permanent Wilting Point (PWP).

- The ceramic plates (1 bar for FC and 15 bar for PWP) are left for 24 hours in water for saturation.
- Undisturbed cores of disturbed soil samples in rubber rings are carefully placed on the plate and allowed to saturate overnight. Care is taken to ensure that proper contact is maintained between the soil sample and ceramic plate surface.
- The saturated samples along with the ceramic plates are placed in the pressure chambers (extractors) which are then carefully bolted. Care should be taken to place the plates in the appropriate chambers as they are also rated for certain applied pressures.
- Through the control valves, pressure from the compressed air supply unit is applied gradually to the two chambers containing the sample.
- The applied pressure is maintained for 48 hours or till water stops flowing out of the chamber.
- The chambers are quickly dismantled after releasing the pressures and the soil samples transferred to moisture boxes immediately and their fresh weight taken. The data are recorded on the observation sheets provided.
- The moist soils samples are then placed in a hot air oven at 105^0c for 24 hours. Their dry weights are recorded.

- The amount of water held at the two applied pressures are calculated on weight basis and converted into volumetric soil water content using the bulk density values.

Estimation of available water

Available water in various soil layers can be calculated from the field capacity (FC) and permanent wilting point (PWP) values by applying the formula as given below:

$$\text{Available water (AW)} = \frac{(FC - WP).pb}{100} \text{ (cm of water/cm of soil)} \quad ...1$$

Where FC is per cent moisture content on weight basis at field capacity level WP is per cent moisture content on weight basis at wilting point and pb is bulk density (g cm^{-3}).

Total available water in the root zone can be computed by integrating the AW values of different layers. The term available water fraction (AWF), which is commonly employed in context of irrigation scheduling of different crops, is defined as below:

Actual water present (cm) = Available water (cm)

Available water

Soil moisture between field capacity and permanent wilting point is referred to as ready available moisture. It is the moisture available for the use generally, fine textured soils have a wide range of water between field capacity and permanent wilting than a coausse texture soil. In contrast sandy soils with their larger proportion of inter capillary pore space release most of their water within a narrow range of potential because of the predominance of large pores. Table presents the range of available water holing capacities of different soil textured groups for irrigation system design.

100% Available soil water = Field capacity- permanent wilting point

Table : Range of available water holding capacity of soils.

Soil type	Per cent moisture based on dry weight of soil		Depth of available water per unit of soil depth of soil (cm/m)
	FC	PWP	
Fine soil	3-5	1-3	2-4
Sandy loans	5-15	3-8	4-11
Silt loans	12-18	6-10	6-13
Clay loans	15-30	7-16	10-18
Clay	25-40	12-20	16-30

Determination of the field capacity of soil

Name: Date:

Location:

Time (day)	Depth (cm)	Estimation of moisture			Soil water content Φ_w (g/g)	Bulk density pb (g/cm^3)	Soil water content Φ_v (cm^3/cm^3)
		Wt of Can + moist soil (g)	Wt of Can + dry soil (g)	Can weight (g)			
1 day 2 day 3 day							

Estimation of field capacity and permanent wilting point by pressure plate method

Name: Soil sample description

Date: Location: Depth:

Pressure (bar)	Sample number	Ring No.	Can No.	Mass of can +moist soil (g)	Mass of can +dry soil (g)	Mass of can (g)	Mass of water (g)	Mass of dry soil (g)	Water content (g/g)	Bulk density (g/cm3)	Water content (cm3/cm3)

Section 2

Determination of Infiltration characteristics of soil

The process of the entry of water into the soil through the soil surface is called infiltration. Most of the water that is applied to the soil surface through irrigation or rainfall, enters the profile through this process- some portion of the applied water can be lost as run-off. Information on the infiltration characteristics of a soil is, therefore, a must for designing efficient irrigation systems and predicting run-off. This information will give us an indication about the advance and recession times, or the magnitude of deep percolation or the maximum permissible application rate for sprinkler or drip irrigation systems.

The infiltration rate of a soil is a measure of its capacity to take in or absorb the water applied to the soil surface. Initially, the rate at which water enters the soil, is very high. This rate decreases with time until a relatively constant value is attained. This is generally referred to as the basic infiltration rate or the basic intake rate of soil.

Infiltration rate have units of volume per unit area per unit time or simply expressed as depth per unit time. Cumulative infiltration, CI, is defined as the total accumulated infiltrated within a specific time. Cumulative infiltration is the integration of infiltration rate and conversely, infiltration is the derivative of cumulative infiltration, that is,

$$CI = \int_0^t i \, dt \qquad \ldots 1$$

$$\text{and} \qquad i(t) = \frac{d(CI)}{dt} \qquad \ldots 2$$

The infiltration rate of soil cannot be directly related to its hydraulic conductivity due to the changing hydraulic gradients and soil water content during the process. But this rate does vary with the saturated hydraulic conductivity of the soil layers. Layers with low hydraulic conductivity values, located either at or below the surface will limit the infiltration rate and in particular, the basic infiltration rate. Surface crusts, silt deposits, machinery tracks, plough layers or clay pans will also influence the infiltration process. A saturated soil will infiltrate water at about the basic infiltration rate.

In case a metallic ring (or cylinder) is being used for infiltration measurements, after water has penetrated in to the soil to a depth below the bottom of the ring, it will start spreading laterally as well as vertically. This will also affect the infiltration rates. To minimize this effect, a buffer pond can be created by constructing an earthen dike around the ring of by driving a larger diameter metal ring concentric with the ring infiltrometer. The use of two concentric metal rings to work out the infiltration characteristics is, therefore, preferred and referred to as the double ring infiltrometer method. This method measures the vertical rate of entry of water into the soil surface.

Equipment and Materials required

Double ring infiltrometer made up of 2 mm rolled steel (30 and 60 cm in diameters for inner and outer rings, respectively and 25 cm height) with hammer, Hook's gauge, timer, source of water, plastic sheet.

Procedure

- The spot at which the infiltration rate is to be determined is carefully cleaned or weeds and levelled.
- The two metal concentric rings (or cylinders) are gradually hammered into the soil. Care is taken to insure that the rings are pushed vertically downwards with least possible disturbance to the soil surface. The rings should be pushed to a depth of at least 10 cm into the soil.
- Water is first poured into the outer (buffer) ring. When water is being applied initially into the inner ring, a piece of plastic or polythene is placed inside the ring to prevent any disturbance at or crusting of the soil surface. This sheet is subsequently removed and the initial reading of the water level is recorded immediately.
- Water is maintained in the buffer ring at about the same depth as inside the ring. The level of water in the rings is maintained between 6-8 cm or the depth of water generally existing during application of irrigation water.
- Observations of the level of water in the ring are taken periodically. Initially the intervals between two consecutive observations are kept short. They become larger with passage of time. They are recorded as indicated in the observation sheet.
- The previous two steps are repeated until two consecutive readings of infiltration rater are obtained.

The cumulative infiltration and infiltration rate can be calculated as shown in the observation sheet proforma.

The cumulative infiltration can be expressed as:

$$CI = at^{n} + b \qquad \ldots 3$$

Where a, n and b are constants determined empirically. A value of 0.6985 has been suggested for 'b'.

The infiltration rate is given by

$$I = \frac{d\,(CI)}{dt} = n.at^{n-1} \qquad \ldots 4$$

Infiltration rate and cumulative infiltration are plotted against time t, on a log-log paper. Both the relationships can be represented by straight lines.

Sample data of cylinder infiltrometer tests

Date:
Crop height
Irrigation No.
Soil moisture
Plot No.
Content

Elap sed time mm	Cylinder No. 1					Cylinder No. 1					Cylinder No. 1					Avg. inf. rate cm/hr	A in ra cr
	Distance of water sources from ref. point		Infiltration during period			Distance of water sources from ref. point		Infiltration during period			Distance of water sources from ref. point		Infiltration during period				
	Before filling cm	After filling cm	Depth Cm	Avg rate cm/hr	Accu Infil. cm	Before filling cm	After filling cm	Depth cm	Ave. rate cm/hr	Accu. Infil. cm	Before filling cm	After filling cm	Depth cm	Ave. rate cm/hr	Accu. Infil. cm		

It is necessary to conduct replicated tests at suitable location in the field. The average values of accumulated infiltration and average infiltration rates are plotted as a function of elapsed time t.

Section 3

Measurement of irrigation water

Units of measurement of irrigation water

Water at rest in reservoirs, tanks, ponds and open wells can be measured in units of volume such as litre, cubic metre, ha-cm, ha-m, gallons, cubic-feet, acre-inch, thousand million cubic feet (TMC). Water flowing in rivers, canals, pipelines, field channels etc. is measured in rate of flow units such as litres per second (lps), cubic metres per second (cumec), cubic feet per second (cusec) ha-cm per hour, ha-m per day, etc.

One ha-cm	10^5 litres a volume necessary to cover an area of one hectare to a depth of one centimetre
One ha-m	10^7 litres
One TMC	One thousand million cubic feet (Dam capacity unit) = 28,320,000m^3
Litre per second	A continuous flow amounting to one litre passing through a point each second
Cubic metre per second	A flow of water equivalent to a stream one metre wide and one metre deep flowing at a velocity of one metre per second.

Methods of measurement

The methods commonly used for can be grouped into four categories

- Volumetric method
- Velocity area method
- Measuring structures
- Tracer method

Volumetric method

Materials required

Container (Plastic bucket or ordinary barrel), stop watch, alkathene pipe.

Procedure

Keep a container of known volume at a place lower than the level of the channel. Divert the water flowing through the channel to the container through a alkathene or plastic tube and record the time required to fill up the bucket by help of a stop watch.

$$\text{Discharge rate (litre/sec)} = \frac{\text{Volume of bucket (liters)}}{\text{Time taken to fill bucket (second)}} \quad ...1$$

Repeat the process 3-4 times and find the average discharge. This method is also used to standardise various irrigation water measuring devices.

Velocity area method

The discharge rate of water in a pipe or open channel by this method is determined by multiplying the cross sectional area of flow section at right angle to the direction of flow by the average velocity of flow.

Discharge (Q) = Area X velocity = A X V ...2

There are again four methods under velocity area method.

a. Float method
b. Use of current meter
c. Use of water meter
d. Co-ordinate method

Float method

Materials A long necked bottle, tape, stop watch, wooden pegs.

Procedure

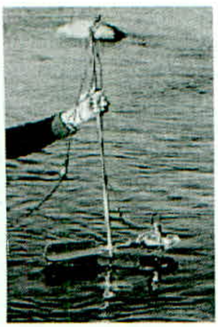
Measure 30 cm length in the straight channel with uniform cross-sectional area and mark the upstream and downstream points. Allow partly water filled long necked bottle to float on the running water well above the upstream point. Note the time when it passes the upstream point as well as the downstream point. Repeat the procedure several times and note the average time taken for the float to cross the 30 m length channel. The velocity is determined by

$$\text{Velocity} = \frac{\text{Length of channel}}{\text{Averag time taken by the float}} \quad \text{...3}$$

The average velocity = Measured velocity x 0.85 (co-efficient) ...4

Discharge or rate of flow = Area x Average velocity

Current meter



Current meter is a small instrument containing a revolving wheel or vane that is turned by the movement of water. The number of revolutions of the wheel in a given time interval is noted and corresponding velocity is reckoned from a calibration table or graph. The discharge is estimated by multiplying the mean velocity of water by the cross-sectional area of the stream. The current meter may be suspended or attached to a rod placed on the open channel

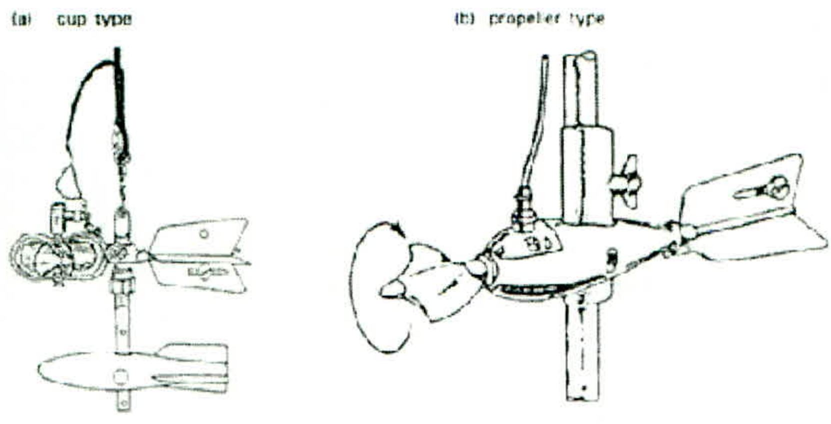


Fig.1. Different types of current meter

Water meter

Water meter has a multiblade propeller made of metal, plastic or rubber, rotating in a vertical or horizontal plane and geared to a totaliser in such a manner that a numerical counter can totalize the flow in any desired volumetric units. The basic requirements are (i) the pipe must flow full at all times, and (ii) the rate of flow must exceed the minimum range. For open channels, the flow must be brought through a pipe of known cross sectional area. Care must be taken that no debris or other foreign materials obstruct the propeller.

Co-ordinate method

This method is used to estimate discharge from flowing wells discharging vertically or from small pumping units discharging horizontally. For pipes discharging horizontally, the horizontal (X) and vertical distance (Y) between centre of the end of the pipe and centre of the jet are to be measured.

$$\text{Discharge (Q)} = \frac{CAX\sqrt{g}}{\sqrt{2Y}} \qquad \text{...5}$$

Where,

Q = Discharge (m^3/sec)

C= Coefficient of contraction, dimensionless (commonly taken as unity)

A = Cross sectional area of pipe (m^2)

g = Acceleration due to gravity (m/sec^2)

X= Horizontal distance from end of pipe to centre of the jet (m)

Y = Vertical distance from centre of the end of pipe to ground surface (m)

For partially filled pipes, discharge can be estimated by multiplying the equation by the percentage of the area of the pipe that is filled at the end of the pipe.

Tracer method (dilution method)

In this method a substance (tracer) in concentrated form is introduced into the flowing water and allowed to thoroughly mix. The concentration of the tracer is measured at the downstream sector. Since, only the quantity of water necessary to accomplish the dilution is involved, this method is independent of stream cross-section and does not require installation of fixed measuring structures.

Water measuring devices

The most commonly used devices for are orifices, weirs, parshall flume and cut throat flume.

Orifices

Orifice is an opening of regular shape on a plate or wall or vertical bulkhead obstructing the flow of water in the channel or canal, through which water passes. The cross sectional area of the orifice is small in relation to that of the channel. This results in complete contraction of the steam flow and the approaching velocity becomes negligible. Orifices may operate under free flow (flow from orifice discharges entirely into air) or submerged (flow discharges into water as down stream water level is above the top of the orifice) conditions. Under free flow condition, again the orifice may be above or below the level of inlet. Flow velocity in orifice depends upon the height of water above the orifice. Free flow orifice can be used to measure comparatively small flow into border strips, furrows or check basin

Discharge through free flow orifice

Orifice below the inlet

$$Q = 0.61 \times 10^{-3} \times L \times H \times \sqrt{2gh} = 0.027L \times H\sqrt{h} \qquad ...6$$

Orifice above the inlet

$$Q = 0.61 \times 10^{-3} \times L \times \sqrt{2g} \times 2 \times h^{3/2} \qquad ...7$$

Discharge through submerged orifice

$$Q = 0.61 \times 10^{-3} \times L \times H \times \sqrt{2g(h_1 - h_2)} \qquad ...8$$

Where,

Q = Discharge through orifice (litres/sec)

L = Length of the orifice (cm)

H = Height of the orifice (cm)

g = Acceleration due to gravity (981 cm/sec^2)

h = Depth of water above the centre of the orifice on the upstream side in case of free flow orifice (cm)

h_1-h_2 = Difference in elevation between the water surface at the upstream (h_1) and down-stream (h_2) faces of the orifice in case of submerged condition (cm)

Meter gate

A meter gate is basically a modified submerged orifice so arranged that the orifice is adjustable in area. The head is same as that under submerged orifice. They are used to control the water flowing from one channel to the other.

Weirs

A weir is a notch in a wall built across a stream through which water flows. The notch may be of rectangular, trapezoidal or triangular (90^0-V) shape.

Rectangular weirs are of two types

a) Suppressed rectangular weir

When the crest length of the weir is equal to the width of the upstream channel it is called suppressed weir.

$$Q = 0.0184\ LH^{3/2} \qquad ...9$$

b) Contracted rectangular weir

When the crest length is less than the width of the upstream channel. The contraction may be in both ends (complete end contraction) or only in one end (one end contraction)

In complete end contraction $Q = 0.0184\ (L-0.2H)\ H^{3/2}$ ...10

In one end of contraction $Q= 0.0184\ (L-0.1H)\ H^{3/2}$ ...11

Where,

Q = Discharge through rectangular weir (litres/sec)

L = Length of crest (cm)

H = Height of water above the crest (cm)

(ii) Trapezoidal or Cipolletti weir

The weir has in built complete end contraction. The slope of the side wall is 4:1.

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

$$Q = 0.0186\left(\frac{L_1 + L_2}{2}\right)H^{3/2} \qquad \text{...12}$$

Where,

Q = Discharge (litres/sec)

L_1 = Crest length (cm)

L_2 = Length of free water surface in the crest (cm)

H = Height of water on crest (cm)

(iii) 90^0 V notch (triangular weir)

It is also a self contracted weir and is commonly used to measure small and medium flow. The discharge is

$$Q = 0.0138\ H^{5/2} \text{ litres / sec} \qquad \text{...13}$$

Where,

H = Height of water above the apex of the notch (cm)

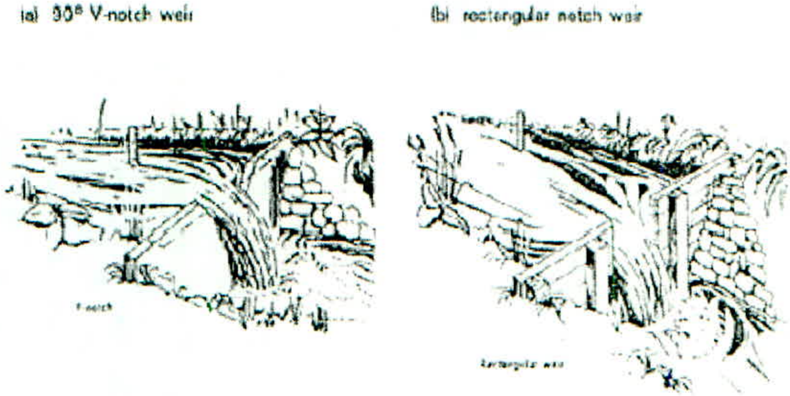


Fig. 2. Measuring stream flow with sharp-crested were

Flumes

Parshall flume (Venturi flume)

The name of the flume goes after the name of its inventor, R.L. Parshall (1950). It is an open channel type self cleaning water measuring device that operates with a small drop in head. The flume has three sections. Upstream section is having converging walls towards the throat and the floor is level. The middle one is the throat section with parallel walls and levelled floor. The walls of the downstream section diverge towards the outlet and the floor is inclined upward. The size of the flume goes after the width of the throat section. Sizes ranging from 2.54 cm to several meters are available, but for small field and experimental purpose 7.5 cm size is suitable.

Discharge through the flume can occur under either free flow or submerged flow conditions. When the elevation of 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, the flow is free flow, or else it is submerged. It is assessed by measuring the height of water at both upstream section and downstream section. If the ratio of downstream section/upstream section is less than 0.5 for 7.5 cm, the flow is considered free flow or else it is submerged. For free flow condition only upstream section is measured, whereas for submerged condition both upstream section and downstream section values are required. The flume has the ability to withstand a relatively high degree of submergence over a wide range of back water condition.

Discharge rate for different flumes have been calibrated and are given in tables for variable upstream section and downstream section/upstream section values (Tables).

The generalised discharge equation for free flow Parshall flume is

$$Q = 4.W.\ Ha^{1.522}\ W^{0.226} \qquad \ldots 14$$

Where,

Q = Discharge (litres/sec)

W = Flume size (cm)

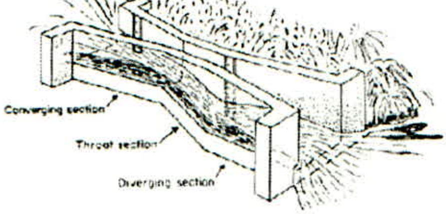


Fig.3.Line digram of a parshall flume

Fig. 4. Field construction of a parshall flume

(ii) Cut throat flume

It is an improvement over Parshall flume and is developed by Skogerboe, Hyatt, Anderson and Eggleston (1967). The flume has level bottom and vertical walls but has no throat. So easy to construct and install even in concrete line channel. The flume length may vary from 4.5 cm to 3.0 m and the width ranged between 2.5 cm to 1.8 m. it can operate either in free flow or submerged condition.

Installation of weirs

Select a long straight channel (30cm).Select proper weir size and place it at the right angle to the direction of flow towards the end of the channel.

Recommended weir sizes	
Max. and Min. head (ft)	Crest length (ft)
0.2-0.75	1.0
0.2-0.85	1.5
0.2-1.00	2.5

Table: Free-flow discharge values for Parshall flume (litres/sec)

Head (cm)	Throat width (cm)			
	7.5	15	23	30
3	0.8	1.4	2.6	3.1
4	1.2	2.3	4.0	4.5
5	1.7	3.3	5.5	7.0
6	2.3	4.4	7.2	9.6
7	2.9	5.4	8.5	11.4
8	3.5	7.2	11.1	14.4
9	4.3	8.5	13.5	17.7
10	5.0	10.2	15.9	21.1
11	5.8	11.6	18.1	23.8
12	6.7	13.5	21.1	27.5
13	7.5	15.0	23.3	31.0
14	8.5	17.3	26.7	35.0
15	9.4	19.2	29.5	38.7
16	10.4	21.2	32.5	42.7
17	11.4	23.2	35.6	46.7
18	12.4	25.3	39.0	51.2
19	13.6	27.8	42.5	55.0
20	14.3	30.0	45.8	59.7
21	15.8	32.7	49.3	64.7
22	17.1	35.2	53.3	69.8
23	18.2	37.7	56.8	74.0
24	19.4	40.1	60.5	79.0
25	20.7	42.7	64.5	84.1
26	22.0	45.7	69.3	89.0
27	23.3	48.1	72.4	94.3
28	24.8	51.3	76.7	100.0
29	26.0	54.0	80.7	105.1
30	27.5	57.3	85.2	111.0

The flow depth (H) should not be less than 5 cm or more than 2/3 rd of crest width. Weir wall must be vertical. The weir crest should be above the bottom of the approach channel by at least twice the depth of water flowing above the crest level (2H). A minimum distance of about twice the depth of flow should be maintained between the end of the weir crest and the bank of the upsteam channel. It is essential to ensure free flow condition. The head measuring scale should be fixed at a distance of about 4H in comparatively still water to one side of the crest. The zero of the scale coincides with the crest level or apex of the triangular weir. Take three concurrent readings of flow depth (H).

Standardisatrion of water measuring devices

Materials

Water measuring devices (orifice, weir and flumes), plastic bucket, measuring jug, stop watch

Procedure

Install the device. Allow water to run for some time. For a fixed time interval collect the flown water in the plastic bucket. Repeat the process 3-4 times and calculate the actual average discharge. Calculate the theoretical discharge either by use of the formula of with the help of table. Accordingly standardise the discharge through the device.

Measurement of discharge through open channel

Discharge of water in a channel can be calculated either by Chezy's or Manning's formula. Manning proposed the simplied formula as:

$$Q = AV = A\frac{R^{2/3}S^{1/2}}{n} \qquad \text{...15}$$

Where,

Q = Discharge (m^3/sec)

A = Cross sectional area of channel (m^2)

V = Mean velocity of flow (m/sec)

R = Hydraulic radius (m)

S = Hydraulic slope (dimensionless)

n = Manning's roughness co-efficient (from table)

Materials: Measuring scale, tape

Procedure: Select the straight section with uniform cross sectional area of an open channel. Peg mark 2-3 spots. Measure the depth of water, bottom width, channel grade and side slope at each spot and calculate the discharge. Average out the discharge for all spots to find out the mean discharge of water in the channel.

Problem

In a trapezoidal earthen channel of grade 0.2 per cent, bottom width 30 cm and side slope of 1.5 to 1, water is flowing at a depth of 24 cm. Calculate the discharge of water in the channel. (Manning's roughness co-efficient = 0.025).

Solution

Length of wetted side = c = $\sqrt{24^2 + 16^2}$ = 28.8 cm

Wetted perimeter (P) = b + c + c

$= 30 + 28.8 + 28.8$

$= 87.6$ cm

Length of top width (t) = 30 + 16 + 16 = 62 cm

Cross sectional area (A) = ½ (b + t) x d

$= ½ (30 + 62) \times 24$

$= 1104\ cm^2$

$$\text{Hydraulic (R)} = = \frac{A}{P} = \frac{1104\ cm^2}{87.6\ cm} = 12.6\ cm$$

$$\text{Hydraulic slope (S)} = \quad 0.2\% = \frac{0.2}{100} = 0.002$$

Manning's co-efficient (n) = 0.025

$$\text{Velocity} = V = \frac{R^{2/3} S^{1/2}}{n} = \frac{(12.6)^{2/3}(0.002)^{1/2}}{0.025}$$

=9.687 cm/sec.

Discharge (Q) = A X V

$= 1104 \times 9.687\ cm^3/sec$

$= 10694.06\ cm^3/sec$

= 10.7 lps

Section 4

Irrigation efficiency and irrigation scheduling

Irrigation efficiency

Irrigation efficiency indicates how efficiently the available water supply is being used for agriculture. Efficiency decreases because of water losses like seepage, deep percolation, evaporation and run off during storage, conveyance, application and distribution of water in an irrigation project. It is defined as the ratio of water output to water input. The ratio of irrigation water used by the crop (s) during its life period to meet its CU and any special need in a field, farm or project to the total volume of water diverted from the source of supply when expressed in per cent denotes the irrigation efficiency for that particular field, farm or project. These are also called as field irrigation efficiency, farm irrigation efficiency or project irrigation efficiency, respectively.

$$E_i = \frac{W_{cu} + W_B - ER}{Wd} \times 100 \qquad ...1$$

Where,

E_i = Irrigation efficiency (%)

W_{cu} = Seasonal consumptive use of the crop or crops

W_B = Water used for special purpose

ER = Effective rainfall

Wd = Irrigation water diverted from the source

As the losses of irrigation water occur at various stages before the plants ultimately utilize it, several partial efficiencies have been defined. For maximum overall irrigation efficiency, the various partial efficiencies should individually be maximum.

Water conveyance efficiency (E_c)

The ratio of irrigation water delivered at the field in let (W_f) to that diverted from the reservoir (W_d) when expressed in percentage is called E_c.

$$E_c = \frac{W_f}{W_d} \times 100 \quad ...2$$

Water application efficiency (Ea)

The ratio, usually expressed in percentage, of irrigation water stored in the root zone of the crop (W_s) to that delivered into the field (W_f) is called E_a

$$E_a = \frac{W_s}{W_f} \times 100 \quad ...3$$

Water storage efficiency (E_s)

It refers to how completely the water needed prior to irrigation (W_n) has been stored in the root zone (W_s) during irrigation.

$$E_s = \frac{W_s}{W_n} \times 100 \quad ...4$$

W_n is usually the field capacity soil misture content.

Water distribution efficiency (E_d)

It evaluates the degree to which water is uniformly distributed throughout the root zone along the run.

$$E_d = (1 - \frac{\bar{Y}}{\bar{d}}) \times 100 \qquad ...5$$

Where, $\bar{d}$ = Average depth of irrigation water stored during irrigation

$\bar{y}$ = Average numerical deviation in depth of water stored from $\bar{d}$

Problem

A stream of 140 litres/sec was diverted from a canal and 110 litres/sec was delivered to the field. An area of 1.5 ha was irrigated in 8 hours. The effective depth of root zone was 1.6 m. The runoff loss in the field was 430 m^3 and deep percolation was negligible. The depth of water penetration was 1.6, 1.5, 1.3 and 1.2 m at four representative points between head and tail end of the field. The available moisture holding capacity of the soil was 25 cm/m depth of soil. Irrigation was given at 50 per cent depletion of available soil moisture. Calculate the conveyance, application, storage and distribution efficiencies.

Solution: W_d = 140 litres/sec.

W_t = 110 litres/sec.

Conveyance efficiency = $E_c = \frac{W_f}{W_d} \times 100 = \frac{110}{140} \times 100 = 78.57\ \%$

Total water delivered to the field

$$W_f = \frac{110 \times 8 \times 3600}{1000} = 3168\ m^3$$

Total water stored in the root zone during irrigation =

W_s = 3168-430 = 2738 m^3

Application efficiency = $E_a = \frac{W_s}{W_f} \times 100 = \frac{2738}{3168} \times 100 = 86.42\%$

Total water need = $W_n = \frac{1.6 \times 25 \times 50 \times 1.5 \times 10^4}{100 \times 100} = 3000\ m^3$

Storage efficiency = $E_s = \frac{W_s}{W_n} \times 100 = \frac{2738}{3000} \times 100 = 91.26\ \%$

Average depth of irrigation water stored in root zone =

$\bar{d} = \frac{1.6 + 1.5 + 1.3 + 1.2}{4} = 1.4\ m$

Average numerical deviation in depth of percentage from

$$\bar{d} = (\bar{Y}) = \frac{0.2 + 0.1 + 0.1 + 0.2}{4} = 0.15\ m$$

Distribution efficiency = $E_d = (1 - \frac{\bar{Y}}{\bar{d}}) \times 100 = (1 - \frac{0.15}{1.4}) \times 100 = 89.3\ \%$

Problem

Work out the irrigation efficiency of a system when 20% water is lost in conveyance, 10% in the field channels and 25% during application.

Solution

Let 100 m^3 water was diverted from the source

$\therefore$ Water received at field inlet = 100- 20 = 80 m^3

Water lost in field channel = 10%

$$\therefore \quad \text{Balance amount} = 80 - \frac{80 \times 10}{100} = 72\ m^3$$

Water loss during application = 25 %

$$\therefore \quad \text{Balance amount} = 72 - \frac{72 \times 25}{100} = 54\ m^3$$

$$\therefore \quad \text{Irrigation efficiency} = \frac{54}{100} \times 100 = 54\ \%$$

How much to irrigate?

The net quantity of irrigation water to be applied to the soil at each irrigation depends on magnitude of moisture deficit in the effective root zone depth of soil, salinity status and expectancy of rainfall. Under non-saline and non receipt of any rainfall, net quantity of water to be applied is equal to the moisture deficit in the root zone soil to field capacity (FC). Always give irrigation water to bring the soil in effective root zone depth to field capacity.

Net quantity of irrigation water can be determined by knowing:

1. Soil moisture content at start of irrigation,
2. Allowable level of available soil moisture depletion at which irrigation is proposed to be given

$$\therefore d = \sum_{i=1}^{n} \frac{MC_{FCI} - MC_{bi}}{100} \times BD_i \times D_i \qquad ...6$$

$$\text{or } \therefore d = \left[\sum_{i=1}^{n} \frac{MC_{FCI} - MC_{PWPI}}{100} \times BD_i \times D_i \right] \times MAD \qquad ...7$$

Where,

d = Net depth of each irrigation (cm)

MC_{FCI} = Moisture content (%,w/w) of ith layer at FC

MC_{PWPI} = Moisture content (%, w/w) of ith layer at PWP

MC_{bi} = Moisture content (%, w/w) of ith layer just before irrigation

BD_i = Bulk density of ith layer (g/cc)

D_i = Depth of ith layer (cm)

N = Number of layers in the effective root zone

MAD = Management allowable deficit of available soil moisture (ASM) for irrigation. Most of the crops are irrigated at 50% depletion of ASM.

$$\text{Gross irrigation requirement} = \frac{\text{Net irrigation requirement}}{\text{Irrigation efficiency}} \qquad ...8$$

Problem

Calculate the net depth of irrigation from the following data, if irrigation is to be applied at 50 percent depletion of available soil moisture in the 90 cm effective root zone depth of a maize crop.

Depth (cm)	FC (%)	PWP (%)	BD (g/cc)
0-15	14	4	1.5
15-30	13	5	1.5
30-60	14	6	1.4
60-90	12	8	1.4

Solution: Available soil moisture in the effective root zone depth is

0-15 cm $= \frac{14-4}{100} \times 1.5 \times 15$ = 2.25 cm

15-30 cm $= \frac{13-5}{100} \times 1.5 \times 15$ = 1.80 cm

30-60 cm $= \frac{14-6}{100} \times 1.4 \times 30$ = 3.36 cm

60-90 cm $= \frac{12-8}{100} \times 1.4 \times 30$ = 1.68 cm

Total = 9.09 cm

$\therefore$ Net depth of irrigation $= 9.09 \times \frac{50}{100} = 4.55$ cm

When to irrigate?

Irrigation interval (days)

$$= \frac{\text{(Depth of irrgation + Effective rainfall) (mm)}}{\text{Daily consumptive use (mm)}} \quad ...9$$

When there is no rainfall between two irrigation

$$\text{Irrigation interval (day)} = \frac{\text{Depth of irrigation (mm)}}{\text{Daily consumptive use(mm)}} \quad ...10$$

For designing any irrigation system

$$\text{Irrigation interval (days)} = \frac{\text{Depth of irrigation (mm)}}{\text{Peak consumptive use rate (mm)}} \quad ...11$$

Time to irrigate

Time required to irrigate an area depends upon quantity of water to be applied (area x depth of irrigation), irrigation efficiency and magnitude of discharge. It can be calculated by using the formula

$$E_i \times q \times t = A \times d \quad ...12$$

Where, E_i = Irrigation efficiency, q = Discharge

t=Time required to irrigate an area A

A = Area to be irrigated, d = Net depth of irrigation

Problem

Calculate the time required to irrigate one ha mustard field to a depth of 6 cm. The rate of discharge is 2 cusec and irrigation efficiency is 75%

Solution

$$t = \frac{A \times d}{E_i \times q}$$

$A = 10{,}000\ m^2$

$d = 0.06\ m$

$q = 2$ cusec $= 2 \times 28.32$ litres/sec

$= 2 \times 28.32 \times 10^{-3}\ m^3/sec$

$E_i = 0.75$

$$t = \frac{10{,}000 \times 0.06 \times 10^3}{0.75 \times 2 \times 28.32} sec$$

= 3 hours 55 minutes

Problem

A pump discharges at the rate of 20 litres/sec for 8 hours a day. Calculate the area commanded if the average depth is 8 cm, irrigation interval is 16 days and irrigation efficiency is 80%

Solution

Total discharge in 16 days

$$= \frac{20 \times 8 \times 60 \times 60 \times 16}{1000} = 9216\ m^3$$

Water required to cover one ha to a depth of 8 cm = 10,000 x 0.08 = 800 m^3 Irrigation efficiency is 80%

$\therefore$ Total quantity of water required to irrigate one ha =

$$800 \times \frac{100}{80} = 1000\ m^3$$

$\therefore$ Total area commanded by the pump = $\frac{9216}{1000} = 9.22$ ha

Scheduling of irrigation

Scheduling of irrigation is the process or technique by which the timing and amount of irrigation water application is determined.

Different approaches for scheduling irrigation

A. Soil approach

- Depth-interval and yield approach
- Soil moisture approach
    1. Feel and appearance method
    2. Available soil moisture depletion
    3. Soil moisture tension

B. Plant approach

- Visual symptoms
- Growth indicators
- Indicator plant
- Micro-plot technique
- Critical growth stage
- Leaf diffusive resistance
- Leaf reflectance
- Plant temperature
- Plant water content and water potential

C. Climatological approach

- Transpiration ratio approach
- Irrigation water to cumulative pan evaporation (IW/CPE)

Out of the above approaches for scheduling irrigation the most commonly followed methods are

- Fell and appearance method
- Available soil moisture depletion measured by gravimetric method or Neutron moisture metre
- Soil moisture tension measured by Tensiometer or Gypsum bloc
- Critical growth stage approach
- IW/CPE (Table)

Neutron moisture metre method is already discussed in previous sections. Here we are discussing only tensiometer and gypsum block methods.

Title: Determination of soil moisture potential by tensiometer

Principle: When water filled tensiometer is installed in soil, water moves into and out of the ceramic cup depending upon the soil moisture tension. In a dry soil, water moves out of the cup into the soil thus creates a vaccum in the tube which is measured in the gauge. When desired tension is reached the field is irrigated.

Materials: Soil auger, scale, tensiometer

Tensiometers are of two types i.e., mercury manometer and vaccum gauge. The materials required for making manometer type tensiometer are:

1. PVC tubing of 2 cm diameter and suitable length
2. Porous ceramic cup of 1 bar capacity
3. Araladite gum
4. Mercury pot
5. Nylon tubing of 1-2 mm diameter
6. Rubber stopper

In vaccum gauge type a gauge is fitted to PVC tube, to measure the tension.

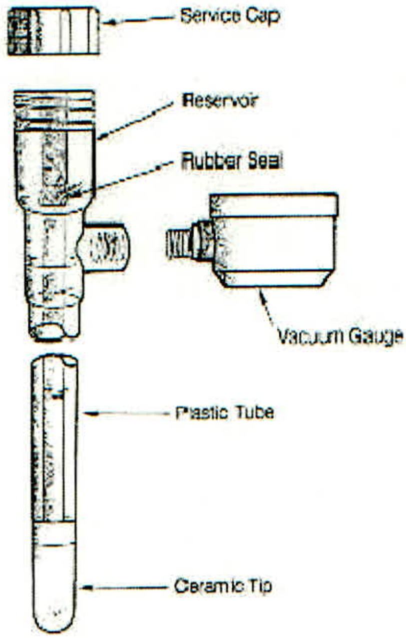


Fig. 5. Different parts of a Tensiometer

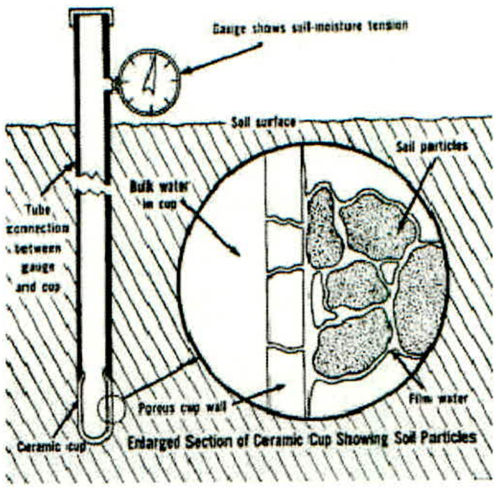


Fig. 6. Installed Tensiometer with enlarge section of ceramic cup showing soil particles

Procedure

Connect the ceramic porous cup to one end of the PVC tube with araladite. Make a hole about 10 cm below the other end of the PVC tube and insert nylon tube or the vaccum in to it gauge. Fix it with araladite. Fill the PVC tube with deaired (boiled and cooled) water. Insert the free end of the nylon tube to a pot of mercury kept on a stand above the soil surface. Now close the other end of the PVC tube with a rubber stopper. The whole system is to be air tight and the nylon tube connecting the mercury pot should be free from air bubbles. Test the whole tensiometer for cup conductance first by allowing evaporation loss through the cup and then by dipping the cup in a bucket of water. In both the processes change in height of mercury column in the manometer ensures cup conductance.

For installation of the tensiometer select a spot in the field which will not come in the way of usual field operations. Make an auger hole and insert the tensiometer cup to a desired depth so that the wall of cup is in intimate contact with the soil. Fill soil (soil slurry if required) in the hole, compact the soil near the surface and make a small heap around the tube so that water will not seep down along the tensiometer body. Record the mercury height in the manometer or the reading in vaccum gauge 24 hours after installation preferably in morning hours at 8 AM.

Calculation: For manometer type tensiometer soil moisture tension in cm (h)

$$= (12.6\,x - y - z) \qquad \text{...13}$$

where, x = Rise of mercury in nylon tube (cm)

y = Height of free surface of mercury in the pot above soil surface (cm)

z = Depth of installation of tensiometer (cm)

Title: Determination of soil moisture content by gypsum block

Principle: Gypsum block works on the principle of conductance of electricity. The resistance to the flow of electricity is inversely proportional to the moisture content of a medium. So, when electricity is passed through electrodes embeded in the block whose moisture content is in equilibrium with that of soil, the resistance will be low for wet block. The resistance readings are taken in a portable wheatstone bridge and corresponding moisture content is estimated by use of a calibration curve. The resistance reading varies from 400 to 600 ohms at field capacity and 50,000 to 75,000 at PWP.

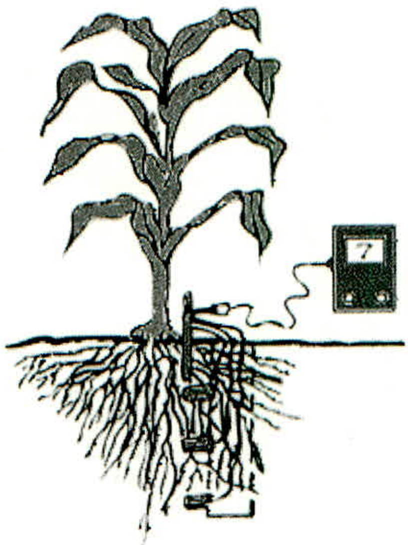


Fig. 7: Gypsum meter installed in the field

Materials

1. **Gypsum block:** It consists of a set of two electrodes placed parallel to each other in a medium of gypsum. Electricity is passed through the electrodes and the resistance to the flow If electricity is inversely proportional to the moisture content in the medium.

2. Bouyoucos moisture meter
3. Post hole auger
4. Metal rod

Procedure

Make a bore with a post hole auger to a desired depth in a convenient spot. Place the previously calibrated gypsum block inside and fill back the bore in small depths layer wise. Tamper the soil with a metal rod to ensure intimate contact of the block with the soil. Normally, 4-5 blocks can be placed in one bore. But do not place two blocks at a vertical interval less than 30 cm. When more number of blocks are placed in one bore, label each block at the surface with their depths. After refilling the bore, heap the soil to a height of about 3 cm near the surface to prevent water stagnation. Irrigate the field and record the readings. Check the resistance reading at field capacity. Obtain the moisture content by use of a calibration curve. In the standing crop, place the gypsum blocks preferably in a row and in between two plants to avoid any disturbance during intercultivation.

Table: Water requirement and critical growth stages of crops

Crop	Duration	Water (days) (cm)	Critical stage requirement	Approx IW/CPE
Rice (transplanted)	90-150	70-120 cm	Tillering, panicle initiation, flowering	-
Rice (direct sown upland)	92-110	37-46	Tillering, panicle initiation, flowering	0.3
Wheat	95-115	35-40	Crown root initiation, flowering milk	0.8
Maize	95-120	50-60	Tasseling Silking, cob development Tillering, grain	0.8-0.9
	Ragi	85-130	40-65	
Filling	0.6-0.8			
Jowar	110-125	55-65	Flowering, grain filling	0.6
Bajra	115-120	45-50	Flowering, grain filling	0.6
Green gram (winter)	75	15	Flowering, pod development	--
(summer)	70	25	Flowering, pod development	0.6
Black gram	90	20	Flowering, pod development	0.6
Horse gram	90	15	Flowering, pod development	0.6
Gram	100	15-20	Flowering, pod development	0.6
Red gram	160	40	Flowering, pod development	0.6
peas	138	15	Flowering, pod development	--
Groundnut (kharif)	110	48	Flowering, pegging, pod development	-
(summer)	120	55	Flowering, pegging, pod development	0.6-1.0
Sesamum	90	25	Flowering, capsule development	1.4
Mustard	100	31	Flowering, siliqua development	0.6-0.8
Castor	130	51	Flowering, capsule development	-
Linseed	85	35	Flowering, pod development	0.6
Jute	120-130	48	Early vegetative stage	-
Sugarcane	300	170	Tillering, ripening	0.6-0.9

Problem

Calculate the cumulative evaporation for scheduling irrigation at IW/CPE of 0.6, 0.8 and 1.0 with 6 cm depth of irrigation water.

Solution

IW =Depth of irrigation water = 6 cm = 60 mm.

* $\frac{IW}{CPE} = 0.6$ $\quad \therefore CPE = \frac{60}{0.6} = 100$ mm
* $\frac{IW}{CPE} = 0.8$ $\quad \therefore CPE = \frac{60}{0.8} = 75$ mm
* $\frac{IW}{CPE} = 1.0$ $\quad \therefore CPE = \frac{60}{1.0} = 60$ mm