LABORATORY MANUAL

Fundamentals of Soil Science
Course Code: SS-101
Credit: 3(2+1)
Semester: 1st

B.Sc. (Hons.) Agriculture
Department of Agriculture

General Laboratory Instructions

1. Always wear a lab coat, gloves, and safety goggles.
2. Do not eat or drink in the laboratory.
3. Handle acids, alkalis, and chemicals carefully.
4. Label all glassware and chemical bottles properly.
5. Record all observations neatly in your lab record book.
6. Dispose of chemicals as instructed by the lab supervisor.
7. Maintain cleanliness in the laboratory at all times.

Practical 1: Study of General Properties of Minerals — Silicate and Non-Silicate Minerals

Title

Study of General Properties of Minerals — Silicate and Non-Silicate Minerals

Objective

To study and identify common silicate and non-silicate minerals based on their physical and chemical properties.

Principle

Minerals are naturally occurring inorganic solids with a definite chemical composition and crystalline structure.

They are broadly classified into two groups:

1. Silicate minerals — contain silicon (Si) and oxygen (O) as their basic building blocks, e.g., quartz, feldspar, mica.
2. Non-silicate minerals — do not have silicon-oxygen frameworks, e.g., calcite, gypsum, hematite.

Identification of minerals is mainly based on their physical properties, such as:

- **Color** – Basic appearance under natural light.
- **Streak** – Color of the powdered mineral when rubbed on a streak plate.
- **Luster** – Appearance of the mineral surface in reflected light (metallic / non-metallic).
- **Hardness** – Resistance to scratching, measured using Mohs' hardness scale (1 = talc, 10 = diamond).
- **Cleavage and Fracture** – How minerals break along specific planes or irregular surfaces.
- **Specific Gravity** – Ratio of mineral density to water density.
- **Acid Test** – Reactivity with dilute HCl to identify carbonates.

Reagents & Apparatus Required

Apparatus

- Streak plate (unglazed porcelain tile)
- Magnifying lens / hand lens
- Hardness kit or common hardness objects:
    - Fingernail (2.5 Mohs)
    - Copper coin (3.5 Mohs)
    - Glass plate (5.5 Mohs)
    - Steel knife (6.5 Mohs)
- Forceps and droppers
- Beakers and test tubes

Reagents

- Dilute HCl (10%) → for carbonate test

- Distilled water → for cleaning samples

Procedure

A. Physical Properties

1. **Color:**
    - Observe the mineral under natural light.
    - Note the visible color carefully.
2. **Streak:**
    - Rub the mineral on a streak plate.
    - Observe the color of the streak.
3. **Luster:**
    - Hold the mineral under bright light.
    - Identify whether it has metallic or non-metallic luster.
4. **Hardness:**
    - Scratch the mineral with objects of known hardness (Mohs scale).
    - Record the approximate hardness.
5. **Cleavage and Fracture:**
    - Break a small piece gently (if possible) and observe the surface:
        - Cleavage → smooth, flat planes.
        - Fracture → irregular, rough surfaces.
6. **Acid Test:**
    - Place a few drops of dilute HCl on the mineral.
    - Effervescence indicates presence of carbonates.

B. **Classification into Silicate & Non-Silicate**

- If the mineral reacts with HCl → mostly non-silicate carbonate (e.g., calcite).
- If no reaction → check for silicate properties.

Observation Table

S. No.	Mineral Name	Color	Streak	Luster	Hardness	Cleavage / Fracture	Acid Test	Type
1	Quartz	White	White	Vitreous	7	Fracture	No reaction	Silicate
2	Feldspar	Pink	White	Glassy	6	Cleavage	No reaction	Silicate
3	Calcite	White	White	Dull	3	Perfect cleavage	Effervescence	Non-silicate
4	Gypsum	Transparent	White	Silky	2	Cleavage	No reaction	Non-silicate

Calculations
No complex calculations in this experiment — only hardness comparisons using Mohs scale.
Result
The given minerals were identified and classified into silicate and non-silicate groups based on their physical properties and acid test.

Viva-Voce Questions

• What is Mohs' scale of hardness?

• Name two minerals that effervesce in dilute HCl.

• Which silicate mineral is most abundant?

• How do you distinguish between quartz and calcite?

EXPERIMENT : 2

Title:

Study of Rocks — Igneous, Sedimentary, and Metamorphic

Objective

To identify and classify rocks into **igneous**, **sedimentary**, and **metamorphic** categories based on their **physical properties, texture, structure, and mineral composition**.

Principle

Rocks are **naturally occurring solid aggregates** of one or more minerals, formed by various **geological processes**.
They are broadly classified into three major groups:

1. **Igneous Rocks**
    - Formed by the **cooling and solidification of magma or lava**.
    - Classified into **intrusive** (formed deep inside the Earth, e.g., granite) and **extrusive** (formed at the surface, e.g., basalt).
    - **Key features**: crystalline texture, absence of layering, hard and compact.
2. **Sedimentary Rocks**
    - Formed by **deposition, compaction, and cementation** of weathered materials or organic matter.
    - Examples: sandstone, limestone, shale.

- **Key features**: presence of **layers (strata)**, may contain **fossils**, softer than igneous rocks.

3. **Metamorphic Rocks**
   - Formed by **alteration of pre-existing rocks** under **high temperature, pressure, or chemically active fluids**.
   - Examples: marble (from limestone), slate (from shale), gneiss (from granite).
   - **Key features**: **banding**, **crystalline texture**, and **hardness**.

Reagents Required

- **Dilute HCl (10%)** → for carbonate test
- **Distilled water** (if needed for cleaning samples)

Apparatus Required

- Hand lens (10× magnification)
- Streak plate
- Hardness testing kit (fingernail, copper coin, glass plate, knife blade)
- Beakers & droppers
- Rock samples (granite, basalt, sandstone, limestone, shale, slate, marble, gneiss)

Procedure

A. Preliminary Examination

1. Observe the **color** and **texture** of the rock sample.
2. Note **grain size** (fine, medium, coarse).
3. Check for the **presence of visible crystals or fossils**.

B. Physical Tests

1. **Streak Test:**
   - Rub the rock sample on a streak plate and record the color of the streak.
2. **Hardness Test:**
   - Use Mohs' hardness scale and compare against known materials.
3. **Acid Test:**

- Place a drop of dilute HCl on the sample.
- **Effervescence** indicates the presence of **carbonate minerals** (e.g., limestone, marble).

C. Classification

- Based on the above observations, classify the sample into **igneous**, **sedimentary**, or **metamorphic**.

Observation Table

Rock Sample	Color	Grain Size	Texture	Effervescence in HCl	Probable Class
Granite	Pink/Grey	Coarse	Crystalline	No	Igneous
Basalt	Black	Fine	Compact	No	Igneous
Limestone	White/Grey	Fine	Layered	Yes	Sedimentary
Sandstone	Brown/Red	Medium	Layered	No	Sedimentary
Slate	Dark Grey	Fine	Foliated	No	Metamorphic
Marble	White	Medium	Crystalline	Yes	Metamorphic

Calculations

No numerical calculations are required for this experiment.

Result

Rocks were successfully identified and classified into **igneous**, **sedimentary**, and **metamorphic** groups based on their **texture, hardness, effervescence, and visible features**.

Precautions

- Handle rock samples carefully to avoid breaking them.
- Use dilute HCl cautiously; avoid direct skin contact.
- Clean all apparatus after use.
- Record all observations neatly.

Viva-Voce Questions

1. What are the three major rock types and how are they formed?
2. Differentiate between **intrusive** and **extrusive** igneous rocks.
3. Name two sedimentary rocks that effervesce with HCl.
4. How can you distinguish marble from limestone?
5. What is **foliation** in metamorphic rocks?

EXPERIMENT : 3

Introduction

Soil develops naturally in layers known as horizons, which together form the soil profile. Each horizon has distinct physical and chemical properties, which influence soil fertility, productivity, and management practices. Studying the soil profile and collecting samples properly are essential steps for laboratory analysis and interpretation.

Objectives

1. To study and describe the soil profile.
2. To identify and record different soil horizons.
3. To collect and process soil samples for laboratory analysis.

Materials Required

Spade/shovel, auger, core sampler, tray, bucket, sieve (2 mm), polythene/paper bags, marker pen, notebook, camera (optional).

Procedure

A. Study of Soil Profile

1. Select a representative site and dig a pit of 1–1.5 m depth.
2. Clean one vertical face of the pit to expose soil horizons clearly.
3. Identify horizons (O, A, B, C, etc.) based on color, texture, and structure.
4. Record observations such as depth, texture, structure, roots, and special features.
5. Draw a neat sketch and take photographs of the profile.

B. Collection of Soil Samples

1. Collect disturbed samples (about 500 g) from each horizon in labelled bags.
2. Collect undisturbed samples with a core sampler for bulk density and porosity.
3. If using an auger, collect soil at fixed depths (0–15, 15–30, 30–60 cm).
4. Label all samples with site, horizon/depth, and date.

C. Processing of Soil Samples

1. Spread soil samples thinly on trays and air-dry in shade.
2. Remove stones, plant residues, and roots.
3. Pass air-dry soil through a 2 mm sieve to obtain fine earth.
4. For organic carbon and nitrogen estimation, grind a portion to pass through a 0.5 mm sieve.
5. Store processed soil in clean, labelled containers for laboratory analysis.

Observation Table

Horizon	Depth (cm)	Color	Texture (feel method)	Structure	Root distribution	Other features (stones, nodules, pores, etc.)
O / Ap						
A						
B						
C						
R (if present)						

Precautions

- Avoid contamination of soil by using clean tools.
- Do not mix soils from different horizons.
- Do not expose samples to direct sunlight while drying.
- Label all samples carefully and legibly.

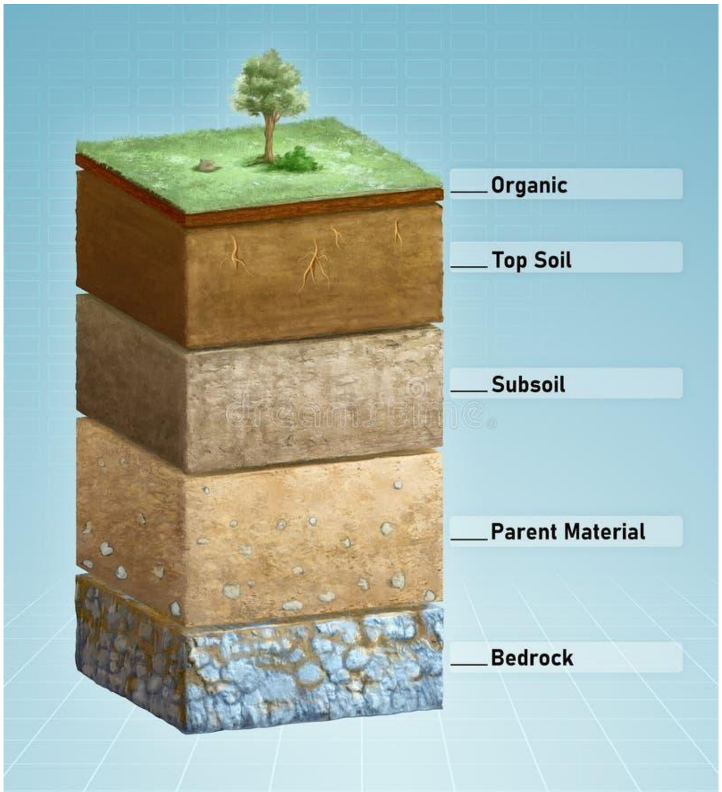

Fig: Soil Profile

Result

The soil profile of the study site was examined. Different horizons were identified, described, and samples were collected, processed, and preserved for laboratory analysis.

EXPERIMENT: 4

1. Study of Soil Texture by Feel Method

Objective:

To determine the soil texture class by the tactile (feel) method.

Principle:

Soil texture refers to the relative proportion of sand, silt, and clay particles. The feel method involves moistening the soil and rubbing it between the fingers to estimate its texture based on stickiness, smoothness, and grittiness.

Materials Required:

- Soil sample
- Distilled water
- Wash bottle
- Porcelain plate

Procedure:

1. Moisten about 25 g of soil with water.
2. Knead it to form a ball.
3. Feel the soil between fingers:
    - Sand: feels gritty.
    - Silt: feels smooth, floury, or soapy.
    - Clay: feels sticky and forms ribbons when pressed.
4. **Roll into a ribbon between thumb and forefinger:**
    - Long ribbon (>5 cm): clayey.
    - Medium ribbon (2–5 cm): clay loam.
    - Short ribbon (<2 cm): sandy loam or loam.
5. **Match observations with the soil texture triangle to classify the soil.**

Result:

The soil sample is classified as ____________(e.g., sandy loam).

2. Soil Texture by Mechanical Analysis (Hydrometer Method)

Objective:

To determine the percentage of sand, silt, and clay using the sedimentation principle.

Principle:

According to Stokes' Law, soil particles settle at different rates in a suspension depending on size:

- Sand → settles fastest
- Silt → medium
- Clay → slowest

Materials Required:

- 50 g air-dried soil
- Sodium hexametaphosphate (dispersing agent)
- Sedimentation cylinder (1 L)
- Hydrometer
- Thermometer
- Stop watch

Procedure:

1. Weigh 50 g soil, add dispersing agent, and transfer into a 1 L cylinder.
2. Make up volume to 1000 mL with distilled water.
3. Shake well to disperse soil particles.
4. Insert hydrometer and note reading at:
    - 40 seconds → % silt + clay in suspension.
    - 2 hours → % clay in suspension.
5. Record temperature correction.

Calculation:

%Sand=(W−R40s)/×100

%Silt=(R40s−R2hr)/W×100

%Clay=WR2hr/W ×100

Where:

- WWW = oven-dry weight of soil sample
- RRR = hydrometer reading (corrected)

Result:

Soil textural class = __________(as per USDA triangle).

3. Determination of Particle Density

Objective:

To determine the particle density (PD) of soil.

Principle:

Particle density is the mass per unit volume of soil solids (excluding pore spaces).

PD=M/V

Materials Required:

- Density bottle (50 mL)
- Weighing balance
- Water bath
- Soil sample

Procedure:

1. Weigh empty density bottle = **W1**
2. Add 10 g oven-dry soil = **W2**
3. Add distilled water and boil gently to remove air.
4. Fill bottle with water and weigh = **W3**
5. Fill bottle with only water and weigh = **W4**

Calculation: **PD** = $\frac{(W2-W1)}{(W2-W41)-(W3-W14)}$

Result:

Particle density of the soil = _________g/cm³ (generally 2.65 g/cm³).

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4. Determination of Soil Porosity

Objective:

To calculate soil porosity from bulk density and particle density.

Principle:

Porosity is the fraction of soil volume not occupied by solids (voids filled with air and water).

Porosity (%)=(1−BD/PD)×100

Materials Required:

- Data of Bulk Density (BD)
- Data of Particle Density (PD)

Procedure:

1. Determine Bulk Density (from core method).
2. Determine Particle Density (from density bottle method).
3. Apply the formula.

Result:

Soil porosity = ________%

EXPERIMENT : 5

To determine the colour of soil using the Munsell Soil Colour Chart.

Principle

Soil colour is an important physical property influenced by:

- Organic matter → **dark brown/black**
- Iron oxides → **red, yellow, brown**
- Calcium carbonate & silica → **light colours (white/gray)**
- Moisture → **wet soils appear darker**

Colour is expressed using the Munsell system, which has three components:

1. Hue → dominant spectral colour (e.g., 10YR, 5R)
2. Value → lightness or darkness (0 = black, 10 = white)

3. Chroma → strength/purity of colour (low = dull, high = bright)

For example: 10YR 5/3 → hue = 10YR, value = 5, chroma = 3.

Materials Required

- Air-dried soil sample
- White porcelain plate or petri dish
- Munsell Soil Colour Chart
- Distilled water (for moist colour)

Procedure

1. Take a small amount of air-dried soil in a white plate.
2. Compare the soil sample with colour chips in the Munsell Soil Colour Chart.
3. Note the Hue, Value, and Chroma of the closest match.
4. Repeat with a moist soil sample (by adding a few drops of water).
5. Record both dry and moist soil colour.

Observation Table

Soil Sample	**Moisture Condition**	**Munsell Notation**	**Colour Name**
Sample 1	Dry	10YR 6/2	Light Brown
Sample 1	Moist	10YR 4/3	Brown

Result

The soil colour of the given sample is ___________(e.g., 10YR 4/3 – Brown, moist).

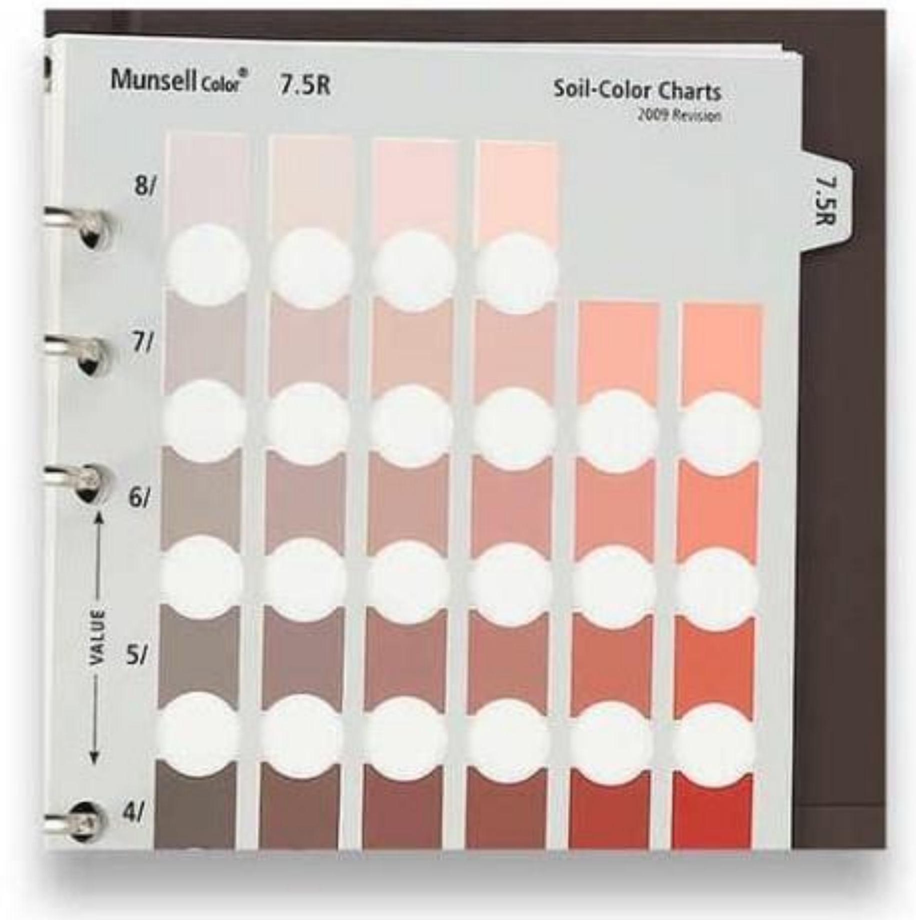

Fig: Soil Color chart given by Munsell

EXPERIMENT: 6

Study of Soil Structure

Objective

To study different types of soil structure and understand their significance in soil management.

Principle

Soil structure is the **arrangement of soil particles (sand, silt, clay) into aggregates**. It affects **aeration, water movement, root penetration, and fertility**.

Types of Soil Structure

1. **Platy** → thin horizontal plates (common in compact soils).
2. **Prismatic** → vertical columns with flat tops.
3. **Columnar** → vertical columns with rounded tops (common in sodic soils).
4. **Blocky** → irregular, roughly cube-like; two types:
   - Angular blocky (sharp edges)
   - Sub-angular blocky (rounded edges)
5. **Granular (Crumb)** → small, rounded aggregates (common in surface soils with organic matter).
6. **Single-grained** → loose sand with no aggregation.
7. **Massive** → solid mass with no visible aggregates.

Procedure

1. Collect undisturbed soil samples.
2. Observe structural forms by breaking clods.
3. Classify according to shape, size, and distinctness.
4. Record observations with sketches.

Observation Table

Sample No.	**Structural Type**	**Grade (Weak/Moderate/Strong)**	**Size (Fine/Medium/Coarse)**
1	Granular	Strong	Fine
2	Blocky	Moderate	Medium

Result

The given soil samples exhibited **granular and blocky structures**.

2. Aggregate Analysis (Wet Sieving Method)

Objective

To determine the **stability of soil aggregates** by wet sieving.

Principle

Stable aggregates resist breakdown when wetted. Aggregate stability is crucial for **infiltration, erosion control, and crop growth**.

Materials Required

- Air-dried soil (25–50 g)
- Set of sieves (e.g., 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.1 mm)
- Mechanical sieve shaker with water (Yoder's apparatus)
- Beakers, oven, balance

Procedure

1. Take 25 g of soil (passed through 2 mm sieve).
2. Place soil on the top sieve of the wet-sieving apparatus.
3. Immerse the sieve set in water and oscillate for 10–15 minutes.
4. Collect soil retained on each sieve, transfer into pre-weighed beakers, and oven-dry at 105 °C.
5. Weigh the aggregates retained on each sieve.

Calculation

Mean Weight Diameter (MWD):

$$\mathbf{MWD = \sum (X_i \times W_i) / \sum W_i}$$

Where:

- • X_i = mean diameter of size fraction (mm)
- • W_i = weight of aggregates in that fraction (g)

Aggregate Stability (%):

$$\mathbf{S = \frac{Stable\ aggregates\ (>0.25\ mm) \times 100}{Total\ Aggregates}}$$

Observation Table (Example)

Sieve size (mm)	Weight retained (g)	Mean diameter (mm)	Xi×Wi
2.0	5.0	2.0	10.0
1.0	7.0	1.5	10.5
0.5	6.0	0.75	4.5
0.25	4.0	0.375	1.5
<0.25	3.0	0.125	0.4

Result

MWD=26.9/ 25 =1.08mm

The Mean Weight Diameter (MWD) of the soil = **1.08 mm**, indicating **moderately stable aggregates**.

Importance of Soil Structure & Aggregate Stability

- Influences **water infiltration, retention, and erosion resistance**.
- Affects **root growth and nutrient availability**.
- Stable aggregates = good soil health and productivity.

EXPERIMENT: 7

Field Capacity (FC)

Objective

To determine the **field capacity** of a soil.

Principle

- **Field capacity** is the amount of water a soil holds against gravity after free drainage stops (usually 2–3 days after rainfall/irrigation).
- It represents the upper limit of available water for plants.

Materials Required

- Soil sample (field plot or undisturbed soil core)
- Core sampler / auger
- Oven (105 °C)
- Balance
- Water supply

Procedure (Field Method)

1. Select a level field and saturate a small plot of soil with water.
2. Cover the plot to avoid evaporation.
3. After **48 hours**, collect soil samples from root zone depth (0–30 cm).
4. Determine **moisture content** by the **gravimetric method**:
   - Take moist soil in a container (W1).
   - Oven dry at 105 °C for 24 hours.
   - Weigh oven-dry soil (W2).
5. Calculate the **field capacity (% moisture content on oven-dry basis)**.

Calculation

$$FC\ (\%) = \frac{W1 - W2}{W2} \times 100$$

Result

Field capacity of the given soil = ______**%**.

2. Water Holding Capacity (WHC)

Objective

To determine the **maximum water holding capacity** of soil under laboratory conditions.

Principle

- WHC is the maximum amount of water a soil can retain against gravity when saturated.

- It depends on **texture, structure, and organic matter**.

Materials Required

- Filter paper
- Funnels / perforated metal cups
- Soil sample (air-dried, sieved through 2 mm)
- Oven (105 °C)
- Balance

Procedure

1. Place a filter paper in a perforated cup or funnel.
2. Fill with **known weight of oven-dry soil** (say 50 g).
3. Slowly add water until saturation (water starts dripping).
4. Allow to drain for 24 hours.
5. Weigh the cup with wet soil (W1).
6. Oven dry at 105 °C for 24 hours and weigh again (W2).

Calculation

$$\mathbf{WHC(\%) = \frac{W1-W2}{W2} \times 100}$$

Result

Water holding capacity of the soil = **______%**.

Importance of Soil Moisture Constants

- Field Capacity (FC): upper limit of plant-available water.
- Permanent Wilting Point (PWP): lower limit (not covered in today's experiment but related).
- **Available Water Holding Capacity (AWC) =FC−PWP**

- **WHC:** indicates soil's ability to retain water for plant use.

EXPERIMENT: 8

Study of Infiltration Rate of Soil, Determination of pH & Electrical Conductivity

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1. Infiltration Rate of Soil

Objective

To determine the infiltration rate of soil using a double-ring infiltrometer.

Principle

- Infiltration is the process of water entering the soil surface.
- Infiltration rate is the depth of water entering the soil per unit time (cm/hr).
- It depends on texture, structure, organic matter, compaction, and moisture status.

Materials Required

- Double-ring infiltrometer (inner ring ~30 cm dia, outer ring ~60 cm dia)
- Hammer and plate
- Measuring scale
- Stopwatch
- Water supply

Procedure

1. Insert the inner and outer rings concentrically into the soil (about 15 cm deep).
2. Pour water into both rings to the same level to minimize lateral flow.
3. Record the fall in water level in the inner ring at specific time intervals (5, 10, 20, 30… minutes).
4. Continue until a constant infiltration rate is reached.

Calculation

$$\textbf{Infiltration Rate (cm/hr)} = \frac{\textbf{Change in water depth (cm)}}{\textbf{Time (hr)}}$$

Observation Table (Example)

Time (min)	**Water depth (cm)**	**Infiltration (cm)**	**Rate (cm/hr)**
0–5	**2.5**	**2.5**	**30.0**
5–10	**1.5**	**1.5**	**18.0**
10–20	**1.2**	**1.2**	**7.2**
20–30	**1.0**	**1.0**	**6.0**

Result

The basic infiltration rate of the soil = 6.0 cm/hr.

2. Determination of Soil pH

Objective

To determine the soil pH by potentiometric method.

Principle

- Soil pH measures soil reaction (H^+ ion activity).
- It influences nutrient availability, microbial activity, and soil fertility.

Materials Required

- Soil sample (air-dried, 2 mm sieved)
- pH meter (calibrated with buffer solutions pH 4.0, 7.0, and 9.2)
- Distilled water
- Beakers (50 mL)
- Glass rod

Procedure

1. Weigh 20 g soil into a beaker.

2. Add 50 mL distilled water (soil:water = 1:2.5).
3. Stir thoroughly and allow to stand for 30 minutes.
4. Standardize the pH meter with buffer solutions.
5. Dip the electrode into the soil suspension and record the pH.

Result

The soil pH = ______(e.g., 6.5 – slightly acidic).

3. Determination of Electrical Conductivity (EC)

Objective

To determine the electrical conductivity of soil using a conductivity bridge/EC meter.

Principle

- EC measures the salt concentration (soluble ions) in soil solution.
- High EC → salinity problems; Low EC → nutrient deficiency.

Materials Required

- Soil sample (20 g, 2 mm sieved)
- EC meter (conductivity cell, calibrated with 0.01 N KCl solution, EC = 1.41 dS/m at 25 °C)
- Distilled water (50 mL)
- Beaker, balance, filter paper

Procedure

1. Take 20 g soil in a beaker, add 50 mL distilled water (1:2.5 ratio).
2. Shake well and let settle for 30 minutes.
3. Filter the suspension through Whatman filter paper.
4. Calibrate the EC meter with KCl solution.
5. Immerse the electrode in filtrate and note the EC (dS/m).

Result

The soil EC = ______dS/m (e.g., 0.5 dS/m – non-saline).

Importance for Students

- Infiltration Rate: important for irrigation scheduling and soil-water management.
- Soil pH: affects nutrient availability (e.g., P availability is maximum at pH 6.5–7.0).
- Soil EC: helps diagnose salinity/sodicity problems.