CHAPTER 17

ECOLOGY I
SOIL

Soil is a mixture of organic and inorganic materials which forms an ecosystem of living organisms and provides materials for plant growth.

FACTORS AFFECTING SOIL FORMATION

1. Climate
2. Topography
3. Parent rock
4. Organisms
5. Time

IMPORTANCE OF SOIL TO PLANTS (and other other organisms)

1. Provides anchorage
2. Provides medium for microbial activity
3. Provides plant nutrient
4. Source of water for photosynthesis
5. Provides water with dissolved inorganic materials for plants growth.
6. Natural home for other organisms

CONSTITUENTS OF SOIL

- Humus
- Living organisms,
- Soil particles
- Mineral salts
- Air
- Water

Note
Humus and living organisms are referred to as the organic component whilst soil particles, mineral salts, air and water are collectively referred to as inorganic.

The next thing is to study the components one by one.

SOIL PARTICLES

Sources of soil particles:
Soil particles are formed during weathering of rocks.

There are four main types of soil particles based on size. These are gravel, sand, silt and clay.

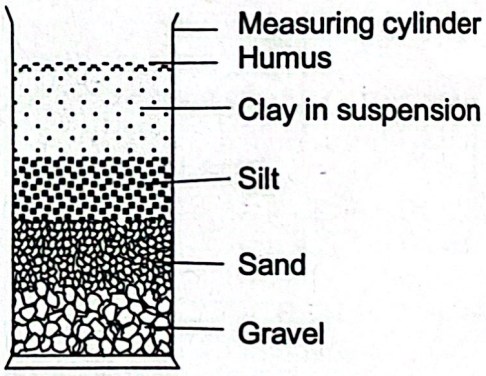
Importance of soil Particles

1. Provides anchorage to plants
2. Source of minerals
3. Water retention for plants.

EXPERIMENT TO SHOW THAT SOIL CONTAINS DIFFERENT SIZES OF PARTICLES (SEDIMENTATION).

This method is referred to us **sedimentation.**

Materials
Garden soil, water, sodium carbonate (Na_2CO_3), $250cm^3$ measuring cylinder/glass jar



Method

- Put some quantity of soil in a $250cm^3$ measuring cylinder about half filled.
- Add sufficient amount of water containing Na_2CO_3 to cover the soil sample.
- Cover the mouth of the cylinder with your palm and shake thoroughly
- Leave to stand on a levelled bench for about 30 minutes (or sometime)

Observation

- Soil sample settles in different layers according to size and weight of particles
- Gravel, the heaviest settles at the bottom
- This is followed by coarse sand and fine sand.
- Sand layer is followed by a suspension of fine particles/suspension of clay which makes the water cloudy.

- Humus and dead organic matter float on the surface of the water.

Conclusion
Garden soil is a mixture of particles of different sizes in different proportions.

Note
In an experiment meant to determine the relative amount of different particles, the same procedure is followed and
The depth/ height of each layer is measured and then divided by the total height of soil in the cylinder.

Precautions
1. The mixture of soil and water should be shaken thoroughly
2. Na_2CO_3 should dissolve in the water to facilitate the process.

SOIL WATER

Sources of water to the soil:
Precipitation/rainfall and irrigation

Factors affecting water content of soil
1. Rain
2. Drought,
3. Humidity of air
4. Proportion of clay
5. Proportion of humus.

Importance of soil water
1. Raw materials for photosynthesis
2. Aids decomposition
3. Medium of transport
4. Transpiration to control temperature of plants.
5. Activates enzymatic activities
6. Aids germination
7. Provides turgidity/support in plants
8. Improves soil fertility.

EXPERIMENT TO FIND THE PERCENTAGE OF SOIL TOTAL WATER CONTENT

Materials
Garden soil, evaporating dish (crucible), stirring rod, weighing balance, oven and desiccator.

Method
- Weigh an empty crucible and record the mass (M_1)
- Half-fill a crucible with a sample of soil
- Weigh the crucible with soil and record the mass (M_2)
- Dry the soil in the crucible in an oven at about 105^oC for about 30 minutes
- Place the soil in a desiccator and leave it to cool
- Weigh the crucible with soil after cooling
- Repeat heating cooling and reweighing until consistent mass value is obtained (until there is no further change in the weight of the soil)
- Record the consistent mass (M_3)
- Obtain the mass of fresh soil before heating by subtracting mass of empty crucible from mass of crucible with soil before heating($M_2 - M_1$)
- Determine the mass of water in the soil by subtracting mass of dry soil from mass of soil before heating($M_2 - M_3$)

$$\text{Percentage of water} = \frac{\text{Mass of water}}{\text{Mass of fresh soil}} \times 100$$

$$= \frac{\text{Difference in soil mass}}{\text{Mass of fresh soil}} \times 100$$

$$= \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Conclusion
Water forms part of soil but its percentage varies with different soils.

Precautions
1. Heating and reweighing should be repeated until consistent mass values are obtained.
2. Heated soil should be cooled in desiccator to avoid absorption of atmospheric moisture.

FORMS OF WATER IN SOIL

Gravitational water/ underground water or water table
Excess water that **drains out** of pore spaces and sinks to the bottom and forms water table on the surface of impermeable parent rock.

Capillary water
Water held against the force of gravity. It occurs in narrow (pore) spaces between soil

particles where it is **loosely** held around soil particles.

Water readily available for absorption by roots of plants

Capillary water is made up of

a. Rain water molecules that do not sink to the bottom but are loosely held around soil particles.

b. Gravitational water rising by capillary action to fill any spaces between the soil particles.

Hygroscopic water

Thin film of water **closely** adhered to the surface of soil particles and not readily available for plants use. It can hardly be absorbed by the roots of plants.

SOIL HUMUS

Organic matter in soil refers to all dead animals and plants and their organic wastes. Undecomposed component of the organic matter is referred to as litter whilst the decomposed component, is referred to as humus.

What is humus?

Humus is dead organic matter in a state of continuous chemical decomposition.
It is found mostly in the top soil.

Characteristics of humus

1. It is black or dark brown in colour.
2. It is sticky and binds soil particles together to form aggregates

Importance of soil Humus

1. Improves soil fertility.
2. Major source of nitrogen.
3. Reduces soil acidity/improves soil pH.
4. Reduces evaporation / Improves moisture content.
5. Retains water and mineral salts/improves water holding capacity.
6. Reduces soil erosion by binding soil particles together/Improves soil texture
7. It promotes the activities of microbes and other soil organisms.

Factors affecting Humus Formation in the soil

1. Air
2. Water/high rainfall
3. Temperature/high temperature
4. Calcium

Methods to maintain soil humus content

1 Manuring
2 Mulching
3 Shifting cultivation
4 Crop rotation.

EXPERIMENT TO FIND THE PERCENTAGE OF SOIL HUMUS CONTENT

Apparatus

Evaporating basin or crucible, tripod stand, wire gauze. Bunsen burner, stirring rod, weighing balance, oven controlled by thermometer desiccator, asbestos mat and tongs

Method

- Weigh an empty crucible and record the mass (M_1).
- Half-fill a crucible with a sample of soil.
- Weigh the crucible with soil and record the mass (M_2).
- Dry the soil in the crucible in an oven at about 105^{o}C for about 30 minutes.
- Place the soil in a desiccator and leave it to cool.
- Weigh the crucible with soil after cooling.
- Repeat heating, cooling and reweighing until consistent mass value is obtained.
- Record the consistent mass (M_3).
- Heat the crucible with dry soil over a Bunsen burner to redness/burn until no more smoke is formed (This stage burns the humus)
- Cool the crucible and its contents in a desiccator.
- Weigh the crucible with burnt soil.
- Repeat heating, cooling and reweighing until consistent mass/constant mass value is obtained (to ensure that no humus remains in the soil)
- Record the consistent mass (M_4)
- Obtain the mass of fresh soil before heating by subtracting mass of empty crucible from mass of crucible with soil before heating($M_2 - M_1$)

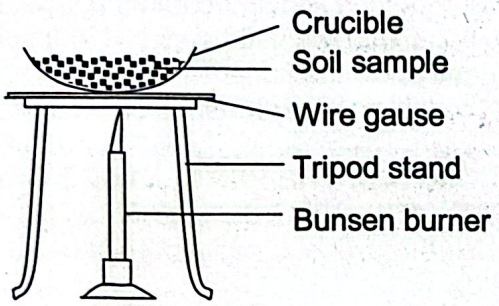
- Obtain the mass of humus in the soil by subtracting mass of burnt soil from mass of dry soil ($M_3 - M_4$)

Percentage of Humus

$$= \frac{mass\ of\ humus}{mass\ of\ freshsoil} x100$$

$$= \frac{Difference\ in\ mass\ of\ dry\ and\ burnt\ soils}{mass\ of\ fresh\ (original)\ soil} \times 100$$

$$= \frac{M_3 - M_4}{M_2 - M_1} \times 100$$



Conclusion
Humus forms part of soil but its percentage varies with different soil samples.

Precautions
1. Heating and reweighing should be repeated until consistent mass values are obtained
2. Heated soil should be cooled in desiccator to avoid absorption of atmospheric moisture
3. The soil should be stirred gently while heating on Bunsen burner.

Worked example:
In order to determine the percentages of soil constituents the following data was obtained
A 30g crucible weighed 70g when filled with fresh sample of soil. Repeated heating in the oven and cooling in a desiccator gave 66.0g, 65.5g, 65.0g, 65.0g.
When the dry soil was repeatedly heated to redness cooled in a desiccator and weighed, 55.0g, 54.0g, 53.5g, 53.0g, 53.0g were obtained

a. Which constituents of soil were being determined?
b. Determine the percentages of each named component in the soil sample
c. Give any two precautions to ensure accurate results

Hint:
a. Water and humus/organic content

b. Percentage of water

Let mass of empty beaker be M_1 = 30g

Let the mass of crucible with fresh soil be M_2 = 70g

Let the consistent mass of dried soil be M_3 = 65.0g

Let the consistent mass of burnt soil be M_4 = 53.0g

$$\text{Percentage of water} = \frac{\text{Mass of water}}{\text{Mass of fresh soil}} \times 100$$

$$= \frac{\text{Difference in soil mass}}{\text{Mass of fresh soil}} \times 100$$

$$= \frac{m_2 - m_3}{m_2 - m_1} \times 100$$

$$= \frac{(70 - 65)g}{(70 - 30)g} \times 100$$

$$= 12.5\%$$

c. Percentage of humus

$$\text{Percentage Humus} = \frac{\text{mass of humus}}{\text{Mass of fresh soil}} \times 100$$

$$= \frac{M_3 - M_4}{M_2 - M_1} \times 100$$

$$= \frac{65 - 53}{70 - 30} \times 100$$

$$= 30\%$$

SOIL AIR

Air is found between soil particles (i.e. in the pore spaces) which are not occupied by water.

Composition of soil air
Air in the soil is mae up of
Oxygen
Carbon dioxide
Nitrogen

Importance of Air to soil

1. Used for respiration by soil organisms and roots of plants
2. Provides atmospheric nitrogen to form nitrates
3. Makes soil porous.

Factors affecting amount of air in the soil

1. Soil particles: larger soil particles have large air spaces
2. Soil water: water fills air spaces in the soil. Amount of air increases as water in the soil decreases. Waterlogged soils have low amount of air
3. Temperature: as temperature increases, soil water evaporares and amount of air increases in the soil

Methods to maintain soil air content

Ploughing

TO DEMONSTRATE THE PRESENCE OF AIR IN A SAMPLE OF SOIL

Method

Add water to a sample of soil and stir the mixture.

Observation

Bubbles of air rise to the surface of the water.

Conclusion

Soil contains air.

EXPERIMENT TO FIND THE PERCENTAGE OF SOIL TOTAL AIR CONTENT

- Determine and record the volume of a tin container by filling it with water and then pouring it into a measuring cylinder (V_1)
- Tightly fill the container with soil (fill the tin tightly with soil, press it down and add more soil until it is impossible to press further).
- The volume of soil is given as the volume of container determined earlier (V_1).
- Empty the soil into a $500cm^3$ measuring cylinder.
- Add sufficient amount of water into the cylinder to cover the soil sample
- Read and record the volume of the content of soil and water (V_2)
- Stir the mixture gently until no air bubbles are seen.
- Read and record the final volume/level of the mixture (V_3)
- Obtain the volume of air in the soil by subtracting the final volume from the initial volume of the mixture ($V_2 - V_3$)

Percentage of air in the sample of soil

$$= \frac{\text{Volume of air in the soil sample} \times 100}{\text{Volume of original soil}}$$

$$= \frac{V_2 - V_3}{V_1} \times 100$$

Precautions

1. All readings should be taken at eye level.
2. The mixture should be stirred or tapped gently with the finger to allow escape of air.
3. The tin container must be clean and dry.

TO COMPARE THE PERCENTAGE OF AIR IN THREE DIFFERENT SOIL SAMPLES

- Use three similar containers of equal volume.
- Fill each with a particular soil sample.
- Use three $500cm^3$ measuring cylinders.
- Transfer each soil sample into one measuring cylinder.
- Cover each soil sample with the same volume of water.
- Determine the volume of air in each sample
- Calculate the percentage of air in each sample from: $\frac{\text{volume of air in soil}}{\text{volume of container}} \times 100$

Hint

The larger the soil particles, the greater the percentage of air in the soil

SOME POINTS TO NOTE

Explain how each of the following can be removed from the soil

a. Water
b. Humus
c. Air

a. Water is removed from a soil sample by heating the soil to dryness (in an oven at 105^oC)
b. Humus is removed by heating the soil to redness/burning the soil. This is accompanied by smoke.

c. Air is removed from the soil by adding water about three times the volume of the soil into the soil. It is thoroughly mixed by stirring or shaking and allowed to stand. Bubbles of air rise to the surface and finally escape to the atmosphere.

SOIL ORGANISMS

Examples of soil organisms
Bacteria, fungi, protozoans, algae.

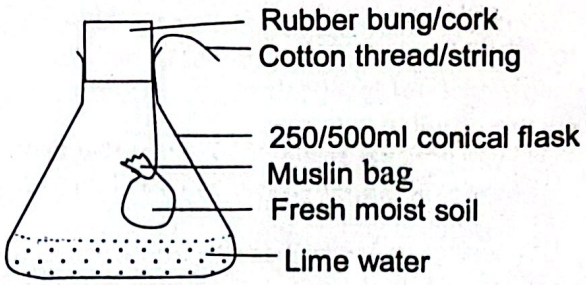
Soil Animals (soil fauna):
Earthworms, millipedes, centipedes, scorpions, rats, wood louse, ants, termites, beetles, crickets.

Importance of soil organisms
1. Aeration of the soil by burrowing activity e.g. earthworms and insects
2. Improves drainage of the soil
3. Formation of humus
4. Fixation of nitrogen
5. Recycling of nutrients

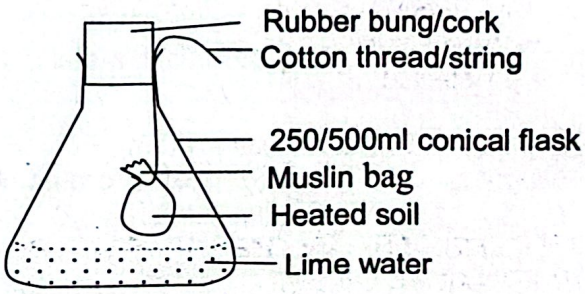
EXPERIMENT TO SHOW THE PRESENCE OF LIVING MICRO-ORGANISMS IN A SOIL SAMPLE

Materials
Muslin bag
Conical flask or test tube
Rubber bung/rubber cork
Thread
Limewater
Garden soil(moist)

Procedure
- Put a handful of fresh garden soil in muslin bag and tighten by means of a thread.
- Add about $30cm^3$ limewater into a conical flask
- Hang the muslin bag containing soil in the conical flask such that the bag does not touch the limewater.
- Cover the mouth of the flask with a cork/bung which also supports the thread/bag:
- Set up a control experiment in a second conical flask the same way but heat the soil sample strongly to kill any living organisms in it.
- Leave the apparatus for about 4 hours/few hours.



Test Experiment



Control Experiment

Observation
- The limewater in the test experiment will turn milky while that of the control experiment remains clear
- More moisture will form on the inner sides of the conical flask of the test experiment

Explanation
- The limewater in test experiment turns milky because it absorbs CO_2 produced by living micro-organisms in the soil during respiration.
- The limewater in the control experiment remains clear because microorganisms in the soil have been killed by strong heating.
- Water vapour from the respiration of micro-organisms forms on the sides of the flask of the test experiment.

Conclusion
Garden soils contain living micro-organisms.

Precautions
1. Soil should be moist
2. Muslin bag with soil should not touch limewater.

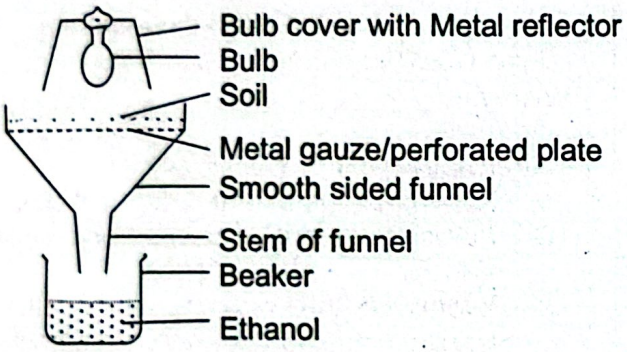
DETERMINATION OF THE TYPE OF LARGER ORGANISMS (ANIMALS) IN THE SOIL

This method involves the use of Tullgren funnel to sample soil invertebrates that have the following **characteristics**:

- Are small in size and
- Avoid light and also
- Love cool places
- Love moist soil.

Materials

Tullgren funnel, 40 Watt electric bulb, metal reflector, 70% ethanol and a beaker



Method

- Put a fresh garden soil in the gauze/sieve in a Tullgren funnel
- Switch a 40 watt electric bulb in a metal reflector above the soil in the funnel.
- Place a beaker containing 70% ethanol beneath the funnel.
- Move the bulb 5cm towards to the soil in every 2 hours until it is 5cm from the soil sample
- Leave the apparatus for 2 days/few days.

Observation

Soil invertebrates move downwards and fall through the sieve into the beaker which contains ethanol beneath. The organisms are counted

Note

- Ethanol serves as a preserving fluid
- Bulb produces heat to drive the animals away
- Metal reflector reflects the heat downward

Examples of animals sampled with this method

Small arthropods such as millipedes, centipedes, mites and insects.

PHYSICAL PROPERTIES OF SOILS

POROSITY

The number of air spaces in the soil

DRAINAGE/PERMEABILITY

How well water can pass through to the lower layers. Drainage is determined by porosity.

CAPILLARITY

The rate at which water can rise up in the soil.
Alternatively, capillarity of soil means:
How well water can rise up in the soil. Capillarity is affected by air spaces/porosity.
Capillarity increases with decreasing size of air spaces in the soil. The smaller the soil particles the smaller the air spaces and the higher the capillarity

Capillarity is higher in clayey soils.

SOIL TEXTURE

The relative proportions of the different sizes of particles in soil
It is a measure of the coarseness and fineness of soil particles.
It is about how the soil feels to touch. It is on the basis that soils are classified as sandy or clayey

Importance/effects of soil texture

1. It determines the amount of air in the soil
2. It affects the degree of drainage
3. It affects the water holding capacity/amount of water retained
4. It affects capillarity in the soil

Types of soil texture

1. Coarse texture – rough to touch : sandy
2. Fine texture – smooth to touch : clayey

SOIL STRUCTURE

This refers to how the soil particles are arranged and stuck together in groups called aggregates which are separated by pores.

Alternatively.
Soil structure is the physical appearance of the soil according to how the primary particles coagulate or are packed and cemented together in groups called aggregates.

Types of soil structure
There are three basic types namely coherent, granular and prismatic structures.
The best type of soil structure is the granular and crumb structure

A crumb structure is formed when the primary particles are cemented together to form rounded aggregates whose diameter is good.
The rounded aggregates are loosely held together making the soil porous.
Crumb structure is found in top soils.

Importance of soil structure
1. It improves air content.
2. It improves water holding capacity.
3. It affects soil erosion: Good soil structure reduces rate of erosion.

Methods to improve/preserve soil structure
1. Mulching
2. Addition of humus
3. Addition of lime

TYPES OF SOIL

These include sandy soil, clayey soil and loamy soil or loam.

SANDY SOIL (Light Soil)

Sandy soil is als referred to as light soil
It is a type of soil with a high proportion of sand particles.

Characteristics of Sandy Soil
1. It has large particles
2. It has large air spaces/Highly porous
3. It retains little water, thus easily drained.
4. It is coarse in texture or rough to touch
5. It has low capillarity due to large pores.
6. It is gritty when wet, thus cannot be moulded
7. Has low nutrient content because it is easily leached.

Note
Sandy soils support scanty vegetation such as the savanna.

Advantages of sandy soil
1. It is not easily water – logged
2. It is highly porous
3. It is light and easy to work with
4. It is well aerated

Disadvantages of sandy soil
1. High drainage hence Easily leached
2. Low capillarity
3. It gets heated in the day
4. Low population of soil organisms
5. Poor/low water retaining capacity.

Methods to improve sandy soil
1. Addition of humus/organic manure
2. Addition of inorganic fertilizers
3. Mixing with clay
4. Mulching with organic materials
5. Growing of legumes or cover crops

CLAYEY SOILS (Heavy soil)

Type of soil with a high proportion of clay particles

Characteristics of clayey soil
1. It has small (fine) and sticky particles
2. Particles are closely packed with small air spaces.
3. It retains a lot of water/has high water holding capacity thus/ poorly drained.
4. It is smooth to touch
5. It has high capillarity due to small pores.
6. It has high nutrient content because it is not easily leached.

Advantages of clayey soil
1. It has high nutrient content.
2. Has high water retention.
3. Has high water capillarity.
4. Has high humus content.
5. Provides strong root hold.

Disadvantages of clayey soil
1. Easily water-logged to provide acidic conditions.
2. Heavy soil, hence difficult to till/cultivate.
3. Contains very little air.
4. Has few soil organisms and low humus

Methods to Improve clayey soil
1. Addition of lime: Lime aggregates or clumps the fine clay particles into larger particles called **crumbs**
   Crumbs have larger air spaces than clay particles and provide better aeration and drainage. The addition of lime to clayey soil

in order to clump tiny particles for good aeration is called **flocculation**
2. Addition of humus.

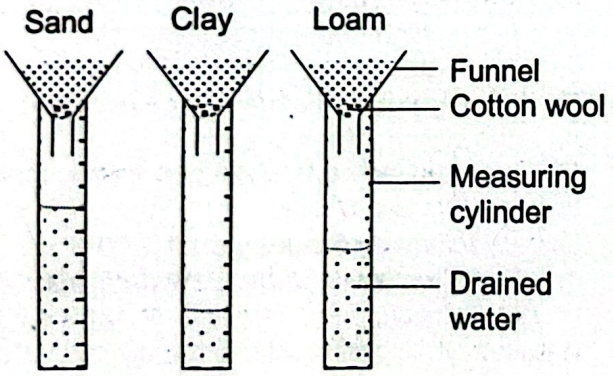
LOAMY SOIL (LOAM)
It is the type of soil with average proportion of sand and clay with a good content of humus which provides adequate conditions for plant growth.

Characteristics of Loam
1. It is a mixture of sand, clay and humus of adequate proportion.
2. It has moderate water holding capacity and drainage.
3. It has moderate capillarity.
4. It has good crumb structure.
5. It has moderate aeration.

Note:
Loam supports forest vegetation.

EXPERIMENT TO COMPARE WATER HOLDING CAPACITY OF DIFFERENT SOILS

Apparatus/materials
Three measuring cylinders, water, dry sand, dry clay, dry loam, funnels, stop clock, cotton wool or glass wool.



Procedure:
- Obtain samples of sandy, loamy and clayey soils.
- Dry each soil sample in an oven to a consistent mass.
- Obtain three filter funnels and plug each with cotton wool or glass wool.
- Insert each funnel in the neck of separate measuring cylinders (100cm^3 measuring cylinders).
- Place equal amounts of oven-dry sandy, clayey and loamy soils and label them as sand, clay and loam respectively.
- Pour equal quantities of water (about 500cm^3) into the soil sample in each funnel at the same time.
- Leave the set up until no water drips into the measuring cylinders.
- Record the volume of water in each cylinder/the volume that has drained through each soil sample.
- Obtain the volume of water retained in each soil sample by subtracting the volume in each cylinder from the quantity added to the soil.

Observation
More water is collected in cylinder of sandy soil, followed by loamy and clayey soil.

Explanation
More water is retained in clayey soil, followed by loamy soil and sandy soil.

Conclusion
Clayey soil has the greatest water retaining capacity followed by loamy soil and sandy soil.

Precaution
1. Glass ware must be clean and dry.
2. Soil samples must be dry.
3. Each funnel is tapped gently on the bench to ensure that all air spaces in the soil are filled.
4. Loamy and clayey soils must be grounded to fine particles before the experiment.

Factors affecting water holding capacity of soils
Texture
Humus content

TO COMPARE THE POROSITY OF DIFFERENT SOIL SAMPLES

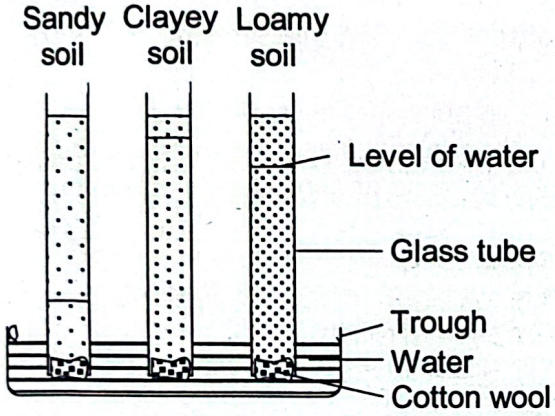
Use the same apparatus and a set up as above.
- Record the time taken for the first drop of water to drip into each cylinder or the time taken for a fixed volume say 2cm^3 of water to collect in each cylinder.

Observation
Water drains through sandy soil faster followed by loamy soil and clayey soil.

Conclusion
Sandy soil has the greatest porosity followed by loamy soil and clayey soil

TO COMPARE CAPILLARITY/CAPILLARY ACTION IN SANDY, CLAYEY AND LOAMY SOILS

Apparatus
Three long glass tubes, cotton wool, dry samples of sand, clay and loam, trough, clock and ruler.



Procedure
- Plug one end of each tube with cotton wool
- Fill the tubes with dry sand, dry clay and dry loam respectively.
- Tap the ends of the tubes gently to ensure the soil samples are tightly packed
- Place the tubes upright in a trough/vessel containing water and support each with a clamp.
- Measure the level of water in each tube at 10 minutes intervals for at least six times.
- Measure the final level of each sample after 24 hours.

Observation
- Water will rise by capillary action in each tube.
- It will be fast in sand, and then followed by loam in the first 10 minutes

Finally the level of water in clay will be the highest, followed by loam and sand the least.

Conclusion
Clay and loam have greatest capillary action.

Explanation of the process
- Clay and loam have great capillarity because:
- Both have fine pore spaces
- Loam has organic materials which absorb water fast

Sand has poor capillarity because
It has large pore spaces

Precautions
1. Soil samples must be tightly packed.
2. Soil samples in all tubes must be easily compressed.
3. Soil samples must be dry.
4. Soil samples must be grounded except sand.

DIFFERENCES BETWEEN SANDY AND CLAYEY SOIL.

Sandy soil	Clayey soil
Coarse texture	Fine texture
Large particles	Small particles
Large air spaces	Small air spaces
Poor capillarity	Good capillarity
High drainage/low water retaining capacity	Low drainage/high water retaining capacity
Poor in nutrients	Rich in nutrients

SOIL PROFILE/SOIL STRATIFICATION

Soil profile is the vertical section through the horizontal layers of soil.
The individual layers are called horizons.
A soil profile consist of four layers (Horizons) namely top soil, sub soil, weathered rock and parent rock or bed rock

A – Horizon/Top soil
- It is the uppermost layer
- It is dark in colour
- Contains a lot of humus/organic matter
- It has good crumb structure
- Most plant roots are found in this layer
- It contains most soil organisms
- The layer is exposed to frequent leaching and erosion.

- Soil fertility increases with thickness or depth of the top soil
- It consists of coarse sand and loam.

B - Horizon/Subsoil
- It is found beneath the top soil
- It is red or reddish brown
- Contains little organic matter
- Has good crumb structure
- It is gravelly, sandy or clayey
- Taproots are occasionally found here
- There is a clay deposit as a result of downward leaching from the top soil.

C- Horizon/weathered rock or soil
- This occurs beneath the subsoil
- Contains no organic matter
- It is hard hence not permeable to water/not porous
- Contains gravels
- Roots cannot penetrate this layer
- Tree roots get their water in the dry season from this layer

D - Horizon/ Parent rock
- Contains rock
- No organic matter
- It is hard
- Not permeable to water
- A source of water and mineral salts for plants in dry season.

IMPORTANCE OF THE VARIOUS LAYERS

Top Soil

It determines soil fertility because it
1. Contains substantial part of the soil nutrients.
2. Contains soil microbes and larger organisms.

Sub soil
1. The nature of the sub soil determines the degree of soil erosion because the more porous or highly permeable it is to water, the more it reduces the degree of the run-off.
2. It determines the water retaining capacity or whether the soil will be water-logged.

Bed rock
1. Source of mineral deposits and soil particles (weathering)
2. Sources of water for plants in dry season.

GENERAL IMPORTANCE OF THE KNOWLEDGE OF SOIL PROFILE
1. The nature of the top soil determines soil fertility and the type of plants/crops grown
2. The nature of the subsoil determines the water holding capacity and aeration
3. The nature of the sub soil determines the degree of erosion.
4. The nature of the bedrock determines the mineral composition of the soil

SOIL ACIDITY (pH of soil)

Soil acidity depends on both organic and inorganic constituents of the soil

Factors causing soil acidity
- Leaching
- Nutrient uptake by plants
- Inorganic fertilizers with acidic radicals
- Presence of compounds of sulphur.

The above factors influence inorganic constituents of the soil as follows:
Physical properties
Availability of certain nutrients

In terms of organic constituent,
Water-logged soils are mainly affected.
Water-logged soils with partly decomposed organic materials tend to be acidic.
Water – logged conditions do not favour the activity of aerobic bacteria but rather anaerobic bacteria whose activity results in the formation of acids.

LEACHING AND SOIL ACIDITY

Tropical soils (high annual rainfall areas) tend to be acidic because certain alkaline substances such as compounds of calcium and potash are washed out of the upper layers of soils by heavy rainfall.

Laterite is an example of an acidic soil which occurs as a result of leaching.
It is poor in compounds of calcium and potash but rich in alumina (aluminium oxide) and Iron oxide

REDUCTION OF SOIL ACIDITY

This is done by liming.

Liming is the addition of lime fertilizers to the soil to reduce acidity of the soil.
In this process, the hydrogen of the complex soil colloid responsible for the acidity is exchanged for calcium ion in lime

Examples of lime fertilizers
Limestone ($CaCO_3$), Quicklime (CaO), Slaked lime $Ca(OH)_2$, wood ash, bone meal, Calcium phosphosilicate $Ca_5(PO_4)_2SiO_4$, MgO, K_2O

Note:
The best lime fertilizer is **limestone**

General advantages/effects of adding lime to the soil
1. It reduces soil acidity
2. It aids in the formation of crumb structure/improves soil structure with large air spaces thereby improving aeration and drainage (flocculation).
3. It improves the performance of soil organisms.
4. It enhances the absorption of essential elements by plants.
5. It increases the nutrient status of the soil.

Reduction of soil alkalinity
Addition of Ammonium sulphate $(NH_4)_2SO_4$

Effects of soil acidity/pH
1. Low pH will reduce the activities of soil micro-organisms
2. Low pH reduces humus content in the soil
3. Low pH reduces the availability of certain plant nutrients.
4. Low pH affects soil structure negatively.
5. Low pH may have toxic effects on roots of plants

TEST FOR SOIL ACIDITY/pH

Materials
Long test tube and bung
Test tube rack
Barium sulphate
BDH universal indicator
Spatula
Distilled water
$10cm^3$ pipette

Method

- Dry the soil sample
- Add about $1cm^3$ of soil sample to a test tube
- Add distilled water (add about $10cm^3$) and shake
- Filter to obtain a solution
- Add BDH universal indicator solution (about $5cm^3$)
- Cover with a bung and shake vigorously (for one minute)
- Allow to settle (for 5mins) for colour changes
- Compare the colour of liquid in the test tube with pH colour chart
- The pH value whose colour matches/corresponds with the colour of the solution in the test is the pH of the soil

Precautions
1. Barium chloride solution should be added to settle clay suspension
2. Distilled water should be previously boiled to expel any carbon (IV) oxide
3. A clean test tube should be used
4. Debris must be removed from the soil sample

WATER LOGGED SOILS

Water logged soils are poorly aerated soils whose air spaces are filled with excess water.
A soil is said to be water logged when its air spaces are filled with excess water

Factors that make soil to be water logged
1. Size of particles/type of soil: clayey soils are easily water logged
2. Position of water table

Effects of water logged soil to plants growth

1. Water logged soils lack oxygen hence roots of plants cannot obtain oxygen for aerobic respiration. As a result, the plants respire anaerobically and alcohol produced in the process is toxic to the plants.

2. Water logged soils are generally acidic because lack of oxygen encourages the activities of anaerobic bacteria which produce acids

SOIL FERTILITY

Soil fertility is the ability of the soil to support growth of a specified plant.

A **fertile soil** is one that supplies all the factors needed for the growth of specified plants.

Characteristics of a fertile soil

- It has good aeration/It is porous
- It has good water holding capacity
- It has good drainage.
- It has adequate humus content
- It has adequate mineral nutrients
- It has correct proportions of soil particles (sand and clay)

FACTORS THAT REDUCE SOIL FERTILITY

1. Erosion
2. Leaching
3. Over cropping
4. Overgrazing
5. Surface compacting
6. Burning of vegetation before planting

EROSION

Erosion is the washing away/removal of top soil with its nutrients by **wind** or **water**

Effects of soil erosion

1. It carries away the fertile top soil which contains most humus, microbes and other soil nutrients
2. Absence of microbes prevents recycling of nutrients
3. Deposits of eroded soil on farms destroy farm crops.

Types of erosion by water

There are three types of erosion caused by water. They are

Splash Erosion

Removal of topsoil by raindrops.

Sheet Erosion

This involves uniform removal of top soil over the whole surface of a slope. It occurs as a result of heavy rainfall. It is the most serious form of erosion.

Rill Erosion

This occurs when rain is less heavy and the mass of water running down the slope produces narrow and shallow channels called rills.

Gully Erosion

This occurs when rain water continues flowing rapidly down rills and forms steep sided channels called gullies.

Erosion by Wind

Strong winds carry top soil away

Examples of such winds are

1. Harmattan wind in West Africa.
2. Monsoon wind in Asia.

WAYS TO REDUCE EROSION

Note that the first four listed below have been explained under maintenance of soil fertility

1. Cover cropping
2. Terracing
3. Contour ploughing: Ploughing along the contours of a slope to reduce speed of water
4. Strip cropping
5. Avoid overgrazing: Animals should not be made to outnumber the capacity that the land can adequately support.

6. AFFORESTATION

Planting of trees. Trees serve as wind breaks and reduce the direct impact of rain drops in the soil.

7. MULCHING

This is the covering of the soil with a suitable material such as grass cutting, saw dust etc.to protect the soil against direct impacts of agents of erosion (rain, running water, wind)

Importance of mulching

1. It prevents overheating of soil.
2. It improves soil moisture content.
3. It adds humus to the soil.
4. Reduces erosion.
5. Adds nitrates and other nutrients to the soil.
6. Increases activity of soil organisms.
7. Improves soil pH.

LEACHING

Leaching is the washing down of important nutrients in the soil to the lower levels below the reach of shallow roots by rain.

Causes of leaching
1. Heavy rainfall
2. Continuous cultivation of land
3. Removal of vegetation.
4. Coarse textured soil/sandy soil/type of soil

Effects of leaching
1. Causes soil acidity
2. Reduces nutrient content

OVERCROPPING
Continuous cropping over a long period of time results in the depletion of soil nutrient.

Effect of over cropping/continuous cropping of the same crop
1. Loss of nutrients
2. High incidence of pests
3. High incidence of diseases
4. Poor growth of crops
5. Reduced yield of crops

OVERGRAZING / CONSTANT GRAZING BY ANIMALS
Constant grazing by a large number of animals in a given area may expose the soil to erosion and surface compacting.

Effects of overgrazing
1. Hooves of animals compact the soil.
2. Reduces permeability of water and air.
3. Increases the rate of erosion.
4. Removes vegetation cover.
5. Reduces activities of soil organisms
6. Destroys soil structure

SURFACE COMPACTING
It is the formation of a dense and hard layer on the surface of the soil.

Continuous/constant walking over the soil by people or livestock makes the soil compact thus affecting nutrient uptake by roots.

Causes of surface compacting
Overgrazing
Human
Effects of surface compacting
1. It reduces air content in the soil.
2. It reduces nutrient uptake because plenty of air enables roots to absorb nutrients.
3. It reduces permeability of water.
4. It reduces the availability of nitrates because the activity of denitrifying **bacteria is encouraged.**

BURNING OF VEGETATION BEFORE PLANTING
This destroys nutrients as well as micro organisms.

Effects of burning of vegetation
1. Destroys nutrients
2. Kills soil organisms
3. Destroys humus
4. Erosion

CONSERVATION OF SOIL

Soil conservation is the protection, preservation and careful management of soil in order to maintain its fertility.

WAYS TO MAINTAIN SOIL FERTILITY
1. Shifting cultivation or bush fallowing
2. Crop rotation
3. Manuring / fertilizer application
4. Cover cropping
5. Strip cropping
6. Terracing
7. Irrigation

SHIFTING CULTIVATION / BUSH FALLOWING
A piece of land is cleared and crops are planted for some number of years. When soil fertility decreases, the plot of land is left for several years for the fertility of the land to be restored.

CROP ROTATION
(The most suitable farming method)

It is a method of growing different types of crops on the same piece of land in a definite cycle over a long period of time to check erosion and maintain soil fertility.

Explanation of crop rotation
- A piece of land is divided into several plots
- Different crops with different nutrient requirements are planted in successive seasons in a definite cycle.
- It is ensured that deep rooted crops follow shallow rooted ones to allow nutrient uptake from different levels of the soil.

- Leguminous crops are included in the rotation to add nitrates to the soil. Microorganisms living in their root nodules fix nitrogen from the atmosphere.
- There is a fallow period after some time.

Principles of crop rotation

1. Deep rooted crops alternate shallow rooted onesin order to take nutrients at different soil levels.
2. Legumes are included in the rotation to add nitrates to the soil.
3. Crops of the same family should not follow each other since they have similar nutrient requirements, pest attack, diseases etc.
4. There should be a fallow period for each plot after a number of seasons of cultivation for the soil to replenish (more humus) etc.

Advantages of crop rotation

1. Checks pests and diseases
2. It checks erosion
3. Addition of legumes add nitrates to the soil
4. Deep rooted crops and shallow rooted crops alternating ensures uptake of nutrient at different levels **of the soil**
5. It preserves virgin forests since it is practised at the expense of shifting cultivation.
6. It also reduces excessive use of inorganic fertilizer and subsequent environmental effect such as pollution

COVER CROPPING

- It is the growing of certain plants (cover crops) to cover and protect the surface of the soil.
- Roots of cover crops hold soil particles together to reduce erosion.
- Leaves of cover crops prevent the direct impact of rainfall and wind on the soil thereby not losing the soil (reducing erosion).
- Leaves also reduce evaporation rate from soil surface and prevents overheating during dry season.
- Legimnous plants add nitrates to the soil

Examples of cover crops

Sweet potatoes,
Crotalaria,
mucuna,
cowpeas,
beans and
Centrosema.

Advantages of cover cropping

1. Reduces rate of erosion in order to maintain nutrients in the top soil.
2. Reduces the rate of evaporation thereby conserving soil moisture.
3. Reduces overheating of soil thereby creating conducive environment for soil organisms.
4. Improves activity of soil organisms.
5. Helps in weed control in order to prevent nutrient uptake by weeds .
6. Leguminous plants enrich the soil with nitrates. e.g. Centrosema sp, cowpea groundnut e.t.c.

STRIP CROPPING

The land is divided into strips along the contours of a slope. In order to check erosion, Strips of narrow-leaved crops alternate with strips of broad-leaved crops.
Or strips of crops alternate with strips planted with cover crops.

TERRACING

Series of steps or terraces are built along contours of a slope to reduce speed of water down the slope and thereby checking erosion. Planting is done in the horizontal portions of the steps while the vertical sections are retained as walls.

IRRIGATION

- Addition of water regularly by artificial means to support plant growth.
- It is done in times or areas with inadequate water supply.
- Water is supplied in adequate quantities to avoid water logging and also not to waste water.

Problems with Irrigation

1. Production of water logged soils.
2. Increasing salinity of soils
3. Stagnant water breeds vectors of diseases such as bilharzia/schistosomiasis, Guinea worm, malaria

MANURING/FERTILIZER APPLICATION

a. Fertilizer application
   - It is the addition of inorganic salts into the soil to replace lost ones.
   - It is done in a careful manner in order to avoid killing of young roots
   - Each plant has its nutrient requirements

b. Manuring
   It is the addition of organic materials or green manure, or farm manure to renew humus content. The humus improves soil texture thereby improving aeration and water holding capacity in the soil

Importance of manuring
1. Adds nitrates to the soil
2. Adds humus to the soil
3. Improves activity of soil organisms
4. Improves soil structure

FERTILIZERS

Fertilizer is a mineral salt added to the soil to replace nutrients.
It should not be applied very close to the plants in order to prevent the plants from withering.

Note:
Fertilizer applied too close to a plant makes the soil solution hypertonic to the plant cells thereby causing plasmolysis in the plant cells causing wilting in the process.

1. A complete fertilizer contains three basic elements namely **nitrogen. phosphorus** and **potassium** and is called NPK fertilizer. Other types of fertilizers contain one of the basic elements and as such bear their specific names as follows

2. Nitrogen-supplying fertilizer
3. Phosphorus-supplying fertilizer
4. Potassium- supplying fertilizer

Summary:
Name the **four** main types of fertilizers

TYPES OF MANURE

1. **Green manure**
   This is made up of young green plants which are mostly leguminous. In green manuring, the plant may be cultivated on the land and then ploughed back into the soil after which it decomposes to form humus.

2. **Animal/Farmyard manure**
   Animal faeces and urine (excreta). It is allowed to decay before added to the soil

3. **Compost**
   Waste plant and animal materials such as dead animals, wood, dead leaves, grass cuttings etc.
   The compost making materials are collected into a heap in order to speed up the rate of decay. Water is added and the heap turned at regular intervals. The product is then spread on ridges.

TYPES OF IRRIGATION

1. **Basin or Flood Irrigation**
   The land is divided into basins using earth wall. The basins are then flooded with water from the main channel.

2. **Sprinkler Irrigation**
   Vertical pipes having sprinklers are laid across the field. Water is pumped and sprinkled on the whole plot.

3. **Trickle Irrigation**
   Underground plastic pipes are laid along the length of plant rows and water made to drip out slowly by each plant.

Disadvantages of sprinkler irrigation
1. It is expensive
2. Irrigated plot may be limited

Advantages of irrigation
1. Farmers do not depend on the weather
2. Crops can be cultivated several times in a year
3. High yield of crops and productivity.

SOIL TESTS

Soil test is the analysis of nutrient level and pH level or acidity of soil in order to determine its fertility.

It involves chemical extraction of the nutrient from the soil and then analysing the mineral content available for plant growth.
It also determines the acidity of the soil.

Importance of soil test
1. To save money
2. Plants do not overgrow or grow poorly
3. Not damage ecosystem with excessive fertilizer application
4. Types of fertilizer and time of application

Refer to test for soil pH on pages 287 and 288

Soil Tests in this section deal with nitrogen, phosphorus and potassium
The first note is the general method for unspecified nutrient.

For the information of readers: Understand the general method very well. Then observe that notes on the tests for nitrogen, phosphorus and potassium are substitutions of necessary steps in the general method

TESTING FOR THE LEVEL OF MINERALS IN SOIL (general method)
Dry the soil and
Remove all debris
Break the soil
Add a universal extracting solution (extracting solution of the mineral being tested) into a test tube
Add the soil into the test tube
Cover the mouth of test tube and shake
Leave the mixture to settle
Filter the solution / or use pipette to remove liquid into another clean test tube
Add the specific mineral test reagent/indicator
Wait for colour to appear
Compare the colour change to a standard on colour chart
Colour shade indicates that, the mineral is Sufficient, Adequate, Deficient or Depleted

Precautions in soil test
1. Avoid touching soil with bare hand
2. Use clean and dry equipment /Test tube should be clean
3. Use dry soil
4. Remove all debris and stone/rock

TO TEST FOR THE LEVEL OF NITROGEN IN A SOIL SAMPLE
Dry the soil and remove any debris
Break the soil
Add nitrogen extracting solution into a clean test tube
Add the soil into the test tube
Cover the mouth of test tube and shake gently
Remove cover and leave to settle
Filter the solution or use pipette to remove liquid into another clean test tube
Add nitrogen test indicator powder
Cover the mouth of test tube and mix gently
Wait for pink colour to develop
Compare the result with nitrogen chart
To determine the level of nitrogen

TO TEST FOR THE LEVEL OF PHOSPHORUS IN A SOIL SAMPLE
Dry the soil and remove any debris
Break the soil
Add phosphorus extracting solution into a clean test tube
Add the soil into the test tube
Cover the mouth of test tube and shake gently
Remove cover and leave to settle
Filter the solution or use pipette to remove liquid into another clean test tube
Add phosphorus indicator reagent and phosphorus tablet
Cover the mouth of test tube and mix gently
Wait for blue colour to develop
Compare the result with phosphorus chart
To determine the level of phosphorus in the soil

TO TEST FOR THE LEVEL OF POTASSIUM IN A SOIL SAMPLE
Dry the soil and remove any debris
Break the soil
Add potassium extracting solution into a clean test tube
Add the soil into the test tube
Cover the mouth of test tube-and shake vigorously
Remove cover and leave to settle
Filter the solution or use pipette to remove liquid
Add potassium indicator reagent and potassium tablet
Cover the mouth of test tube and mix gently
Wait for colour change from purple to blue
Compare the result with potassium chart
To determine the level of potassium in the soil

QUESTIONS

Use the information below to answer questions 1- 4

A. *Sandy soil*
B. *Clayey soil*
C. *Loam*
D. *Silt*

1. Which of the soil types has the highest percolation?

2. Which soil is easily leached?

3. Which soil is less fertile?

4. Which soil is difficult to till?

5. A sample of wet garden soil of known weight was heated to complete dryness and reweighed. The loss in weight is due to loss of
   A. water only
   B. organic matter only
   C. water and organic matter
   D. inorganic matter

6. Bush burning may result in
   A. increase in the acidity of the soil
   B. increase in the activity of soil organisms
   C. return to the soil of lost nutrients
   D. degradation of top soil

7. By which of the following ways can fertility of the soil be improved?
   A. Burning the vegetation before cropping
   B. Cultivating the same crop on the same piece of land
   C. Cultivating only maize and yam on the same piece of land.
   D. Leaving the land to fallow

8. In the sedimentation experiment the layer which settles on gravel is the
   A. colloidal layer of clay
   B. sand
   C. silt
   D. organic matter

9. One reason why organic matter is added to the soil is to
   A. encourage aggregation of soil particles
   B. prevent evaporation of water
   C. facilitate alluviation of nutrients
   D. reduce percolation rate

10. Acidic soils are rich in
    A. alumina
    B. limestone
    C. potash
    D. quick lime

11. Acidic soils are poor in
    A. calcium compounds
    B. sodium compounds
    C. sulphur compounds
    D. alumina

12. All the following can reduce acidity in soils **except**
    A. Ash
    B. $(NH_4)_2SO_4$
    C. Bone meal
    D. Limestone

13. Limestone added to soil
    A. increases nitrogen content of soil
    B. reduces acidity of soil
    C. kills soil organisms
    D. increases weathering

14. Which of the following environments is likely to have acidic soil?
    A. Sea shore
    B. Water-logged soil
    C. Savanna soil
    D. Newly cultivated land

15. The type of erosion in which large channels form on the soil surface is referred to as
    A. gully erosion
    B. rill erosion
    C. sheet erosion
    D. splash erosion

16. Which of the following factors influence soil formation?

    i. soil organism
    ii. topography
    iii. climate
    A. i and ii only
    B. i and iii only
    C. ii and iii only
    D. I, ii and iii

17. Conservation of soil fertility employs crop rotation because
    A. crops are allowed to grow at their own rates
    B. it encourages the healthy growth of plants
    C. it allows utilization of soil nutrients at different levels
    D. different crops grow at the same time

18. Which of the following features can be described as an edaphic factor?
    A. Turbidity of water
    B. Presence of living organisms in the community
    C. Soil pH
    D. Relative humidity of the air.

19. Which of the following statements is not a reason for banning bush burning? It
    A. allows for quick regrowth of grasses
    B. kills soil micro organisms
    C. leaves the soil bare of vegetation
    D. burns off organic soil nutrients

20. Which of the statements below explains why fertilizers are added to soils?
    A. Increasing the humus content of the soil
    B. Improving the water-retaining capacity of the soil
    C. Increasing the nutrient level of the soil
    D. Preventing soil erosion

21. The purpose of treating poor soil with lime is to increase the quantity of
    A. nitrogen
    B. phosphorus
    C. calcium
    D. suphur

22. The treatment of soil with lime supplies it with
    A. calcium
    B. sulphur
    C. phosphorous
    D. nitrogen

23. Fertility of the soil can be renewed by
    A. cutting timber
    B. using weediscides
    C. bush fires
    D. irrigating

24. Lime is added to the soil to
    A. increase the acidity.
    B. decrease the acidity.
    C. precipitate other minerals.
    D. impoverish the soil.

25. Which of the following processes is **not** of soil conservation
    A. Mulching
    B. Deforestation
    C. Fallowing
    D. Crop rotation

26. Tullgren funnel is used to
    A. extract minute soil organisms
    B. measure the amount of rainfall
    C. collect water from habitats
    D. pour liquids into containers with narrow mouth

ANSWERS TO OBJECTIVE TEST

1A 2A 3A 4B 5A 6D 7D 8B 9A 10A 11A
12B 13B 14B 15B 16C 17C 18C 19A
20C 21D 22A 23D 24B 25B 26A

ESSAY

1. a. What is soil texture?
   b. How does soil texture affect soil for plant growth?

2. a. What is soil profile?
   b. How does the knowledge of soil profile benefit a farmer?

3. Describe briefly how you would show that soil is made up of different particles.

4. Describe the effects of
   a. Humus
   b. Soil structure
   c. Soil texture
   d. Porosity
   e. Liming

5. Describe an experiment to investigate the relative proportions of soil particles in a soil sample

6. Explain each of the following terms

a. Flocculation
b. Leaching
c. Mulching
d. Laterite soil

7.
a. What is meant by soil
b. Explain why loam is a fertile soil
c. What are the effects of
   i) Adding animal manure to the soil
   ii) Adding lime to the soil

8. Discuss
   a. **Five** ways in which soil may lose its fertility
   b. **Five** ways in which soil fertility may be maintained or renewed

9. The same crop was grown on a farm land for three consecutive years.
   a. What are the problems the farmer is likely to encounter?
   b. Suggest solutions to the problems you have mentioned in (a) above.

   Hint:
   a.
   - Loss of nutrients
   - High incidence of pests
   - High incidence of diseases
   - Poor growth of crops
   - Excessive use of nutrients

   b.
   - Manuring
   - Addition of fertilizer
   - Crop rotation
   - Land fallowing
   - Use pesticides (agrochemicals)

10. a. List six constituents of soil
    b. State six characteristics of a fertile soil
    c. Describe six ways in which soil fertility can be maintained

11. Give **five** characteristics of a good garden soil

12. Describe an experiment to determine the humus content of a garden soil

13. Name **five** methods to reduce soil erosion

14. Give **five** reasons why loamy soil is best suited for plant growth

15. Explain how crop rotation helps in conserving the soil

16. Describe **three** methods used to maintain soil fertility along a slope

17. Name **five** constituents of soil and give one function of each

18. Describe an experiment to determine humus content in a soil sample.