Draft Study Material

Soil and Water Testing Laboratory Assistant

(QUALIFICATION PACK: Ref. Id. AGR/Q8102)

SECTOR: AGRICULTURE

Grade 11

विद्ययाऽमृतमश्नुते

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NCERT

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Preface

Vocational Education is a dynamic and evolving field, and ensuring that every student has access to quality learning materials is of paramount importance. The journey of the PSS Central Institute of Vocational Education (PSSCIVE) toward producing comprehensive and inclusive study material is rigorous and time-consuming, requiring thorough research, expert consultation, and publication by the National Council of Educational Research and Training (NCERT). However, the absence of finalized study material should not impede the educational progress of our students. In response to this necessity, we present the draft study material, a provisional yet comprehensive guide, designed to bridge the gap between teaching and learning, until the official version of the study material is made available by the NCERT. The draft study material provides a structured and accessible set of materials for teachers and students to utilize in the interim period. The content is aligned with the prescribed curriculum to ensure that students remain on track with their learning objectives. The contents of the modules are curated to provide continuity in education and maintain the momentum of teaching-learning in vocational education. It encompasses essential concepts and skills aligned with the curriculum and educational standards. We extend our gratitude to the academicians, vocational educators, subject matter experts, industry experts, academic consultants, and all other people who contributed their expertise and insights to the creation of the draft study material. Teachers are encouraged to use the draft modules of the study material as a guide and supplement their teaching with additional resources and activities that cater to their students' unique learning styles and needs. Collaboration and feedback are vital; therefore, we welcome suggestions for improvement, especially by the teachers, in improving upon the content of the study material. This material is copyrighted and should not be printed without the permission of the NCERT-PSSCIVE.

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Module 1
Introduction to Soils

Module Overview

Soil is one of the most important natural resources for food production upon which major part of human food is produced. Soil is supporting and nourishing to all forms of life on the earth. Therefore, understanding the soils is crucial for agricultural production. Healthy soil is the basis for the maintenance of healthy ecosystem. Soil is considered as the central pillar of the ecosystem that supports and sustains other ecosystem components such as organisms, water, energy and hence essential for food and nutritional security. In brief without soil life would not have been possible in this earth.

Learning Outcomes

After completing this module, you will be able to:

- Describe the physical properties of soil, including texture, structure, porosity, and color, and their impact on soil behavior and plant growth.
- Explain the chemical properties of soil, such as pH, cation exchange capacity (CEC), nutrient content, and salinity, and their significance for soil fertility and crop productivity.
- Identify the biological properties of soil, including soil microbiota, organic matter content, and decomposition processes, and their role in maintaining soil health and ecosystem functions.
- Discuss the processes of soil formation, including weathering, organic matter accumulation, and horizon development, and how these processes contribute to soil diversity.
- Describe the major soil types found in India, their characteristics, distribution, and suitability for different agricultural practices.

Module Structure

- Session 1: Soil and its Properties
- Session 2: Chemical Properties of Soil
- Session 3: Biological Properties of Soil
- Session 4: Processes of Soil Formation

- Session 5: Soils of India

Session 1: Processes of Soil Formation

India has a total geographical area of 329 Mha. Our country is gifted with different types of soil. This is primarily due to distinct soil tracts and diverse climatic conditions as well as different parent soil material spread over the country. In our country we have most of the soil types found in the world. In this session we will discuss about soils of India.

1.1 Soil genesis

The process of soil formation is called as 'soil genesis' which is a complex process and it takes hundreds of years to form one inch of soil. The soil formation depends upon several factors and soil-forming processes (Figure 1.1).

Hans Jenny (1941), an eminent soil scientist from Switzerland, gave the concept of soil formation/genesis as follows:

$$S = f(cl, o, r, p, t)$$

Here,

S= Soil properties

Active factors
- cl = Climate
- o = Organisms/vegetation

Passive factors
- r = Relief
- p = Parent materials
- t = Time

Fig. 1.1 : Factors influencing soil genesis

The soils are formed through the interaction of the above mentioned five factors, *viz.*, climate, parent material, organisms/vegetation, relief (topography), and time. The climate and organisms/vegetation are active factors in soil formation and their effects are direct and more remarkable. In comparison, the impact of relief, parent material, and time is relatively less apparent and therefore these are called as passive factors.

Soil formation begins with the weathering processes. Weathering is the process of transformation of rocks and minerals into soil. Major types of weathering which takes place simultaneously on the parent materials (rocks) are physical and chemical (Table 1.1).

Table 1.1: Different Types of Weathering Involved in Soil Formation

Weathering	Description
Physical	
Freezing and thawing	Water expands as it freezes. Before winter, the water seeps into cracks freezes, driving the rocks apart.
Heating and cooling	The differential heating and cooling of rocks over a time period sets up stress on rock, can cause the rock to break and fracture thus causing weathering.
Wetting and drying	The frequent wetting of the rock through precipitation, coupled with drying by wind and sun, leads to rapid break down of the rocks.
Root wedging	Plant roots grow into the fractured rocks in search of water and nutrients which further expand the existing fracture as the root grows causing weathering.
Chemical	
Hydrolysis	Hydrolysis occurs when primary minerals react with water to form other products.
Carbonation	Breakdown of rocks by acidic rainwater. In particular, limestone is weathered by rainwater containing dissolved CO_2. The carbonic acid is formed after the reaction of water and CO_2 which dissolves the rocks.
Hydration	It is the chemical combination of water with another substance. The hydrated substances show different physical and chemical properties.
Oxidation-Reduction	This process of oxidation (loss of electron) reduction (gain of electron) in various compounds found in the rocks gets changed from one form to another form leading to its weathering. A parallel analogy of it is iron acquiring rust over time (i.e., oxidation of iron).

Biological	
Disintegration (rock weakening)	The process of biological weathering starts with the weakening of the rocks by microbial activity including lichen and moss and their subsequent disintegration by plants, animals and other microbes. As a result of microbial activity different organic acids are secreted that help in weathering of rock and minerals and also prevent soil erosion.

During soil formation, differentiation among different 'horizons' is developed gradually through different processes such as additions, losses, redistributions and transformations (Table 1.2).

Table 1.2: Different Processes Responsible for Soil Differentiation.

Broad Category	Soil Processes
Additions	Deposition: additions of soil material by wind or water.
	Littering: accumulation of organic material on the soil.
Losses	Leaching: downward removal of soluble materials from soil.
	Erosion: removal of the surface layer of soil.
Redistributions	Eluviation: movement of material out of a horizon.
	Illuviation: movement of material into a horizon.
	Pedoturbation: biological or physical mixing of soil materials.
	Salinization: accumulation of soluble salts in soil.
	Alkalization: accumulation of sodium in soil.
Transformations	Weathering: changes due to exposure to climatic conditions.
	Decomposition: breakdown of mineral and organic materials.
	Humification: conversion of organic material into humus.

	Mineralization: release of mineral constituents from organic matter.
	Synthesis: formation of new mineral or organic species.

We have discussed the various factors responsible for formation of soils along with the different processes which play a role in soil formation. The Fig. 1.2 gives an overall picture of formation of soils of various types.

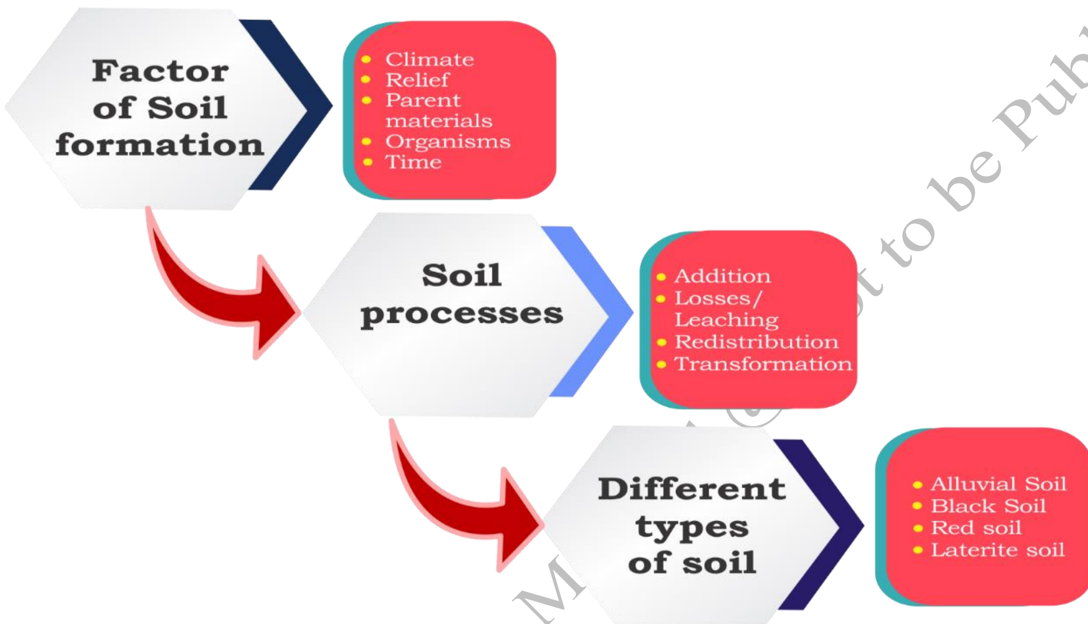


Fig. 1.2: Overall process of soil formation

Check Your Progress

Multiple Choice Questions

1. Which is not a factor of soil formation
   a) Climate
   b) Time
   c) Distance
   d) Relief

2. Leaching and erosion come under which broad category of soil process
   a) Addition
   b) Losses

c) Redistribution

d) Transformation

3. During soil formation, different soil forming processes operate simultaneously in soil, select the correct answer

a) Additions

b) Losses

c) Redistributions

d) Transformations

e) All the above

4. Process of soil formation is also called as

a) Soil erosion

b) Soil degradation

c) Soil deformation

d) Soil genesis

5. In weathering process, freezing and thawing is largely known as

a) Chemical weathering

b) Physical weathering

c) biological weathering

d) Soil genesis

Fill in the Blanks

1. …………. is the process of transformation of rocks and minerals into the soil.
2. During soil formation, differentiation among different…………… is developed.
3. The process where carbonic acid is formed after the reaction of water and CO_2 which dissolves the rocks is called …………………………….
4. …………………. is the process in which chemical combination of water with another substance takes place.
5. ……………… is the process in which loss of electron occurs while ………….. results in gain of electron in various compounds in the rocks.

True or False

1. Hydrolysis occurs when primary minerals react with water to form other products.
2. Soil formation does not depend on numerous factors and soil-forming processes.
3. Soil forms through the interaction of five different factors.
4. Wetting and drying is type of chemical weathering.
5. Different horizons or layers are not developed during soil formation.

Session 2: Soil and its Properties

Soil, land and earth are often used interchangeably. However, soil is the three-dimensional natural body on which vegetation grows. The soil is outermost layer of earth similar to 'peel of an orange'. Soils are formed by weathering of rocks and minerals. Weathering can be due to physical, chemical or biological agents. The organisms such as lichen, mosses and plants are grown on the rock, release chemical substances and root exudates that decompose rocks, resulting in soil formation. The soil rich in nutrient is considered as fertile and the entire agriculture production is dependent on the soil fertility. Thus, we can say higher the soil health, higher would be the agricultural production. The production of cereal, pulses, oil crops, spices, etc. are dependent on soil health.

2.1 Soil as a medium of plant growth

Soil provides all essential nutrient elements which are required for plant growth and its life cycle.

2.2 Definition of soils and its components

The term 'soil' is derived from the *Latin* word "solum" which means floor. Soil is a thin layer of Earth's crust, which serves as a natural medium for plant growth. It is a three-dimensional natural entity consisting of different layers which comprise of minerals, organic matter, living organisms, air and water. However, the Indian Council of Agricultural Research (ICAR) defines soil as sub aerial natural object at dynamic equilibrium with its environment. This sub aerial natural object exists either in the open air or on the earth's surface but not under water or underground.

2.3 Soil and its components

Soil is the outer-most thin layer of earth's crust which serves as medium for growth of plants. Rocks are the parent material over which corresponding soils are formed by the process of weathering.

2.3.1General features of soil

- It is a dynamic natural body and even to form an inch of soil it takes the time of hundreds of years
- The soil properties vary from one geographical region to another.
- All soils are differentiated into distinct horizons or layers. The soil profile comprises of different

  Horizons/layers as shown in Fig. 1.3.
- Different soils have different physical, chemical and biological properties.
- It is a living entity consisting of billions of micro-organisms in one teaspoon of soil.

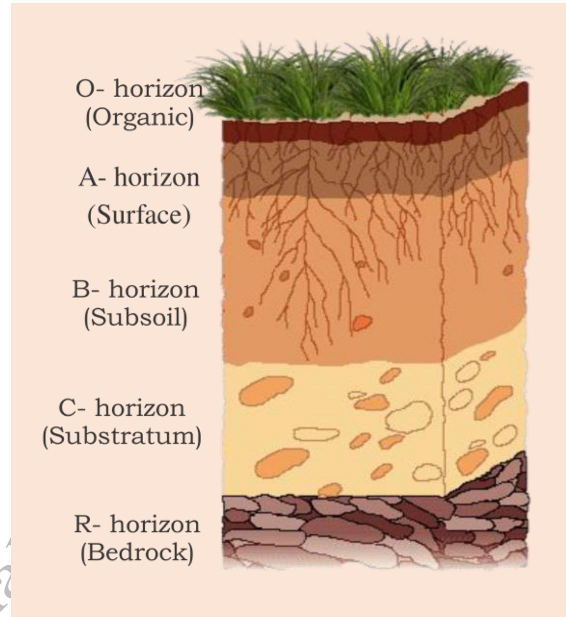


Fig. 1.3: Soil profile

Soil means different things for different people

- **Layman:** Dirt or Debris
- **Pot maker:** Raw materials for earthenware
- **Home owner:** Material for house construction and gardening
- **Mining engineer:** Debris covering the rocks
- **Civil engineer:** Material on which road or house bed is built
- **Agriculturist:** Habitat for plants and food production

2.3.2 Components of soil

Soil is not a homogeneous medium, it contains air, water and minerals as described in the Fig.1.4. The constituents of soil are broadly classified as:

(i) Mineral matter (45%)
(ii) Organic matter (5%)
(iii) Soil air (20-30%)
(iv) Soil water (20-30%)

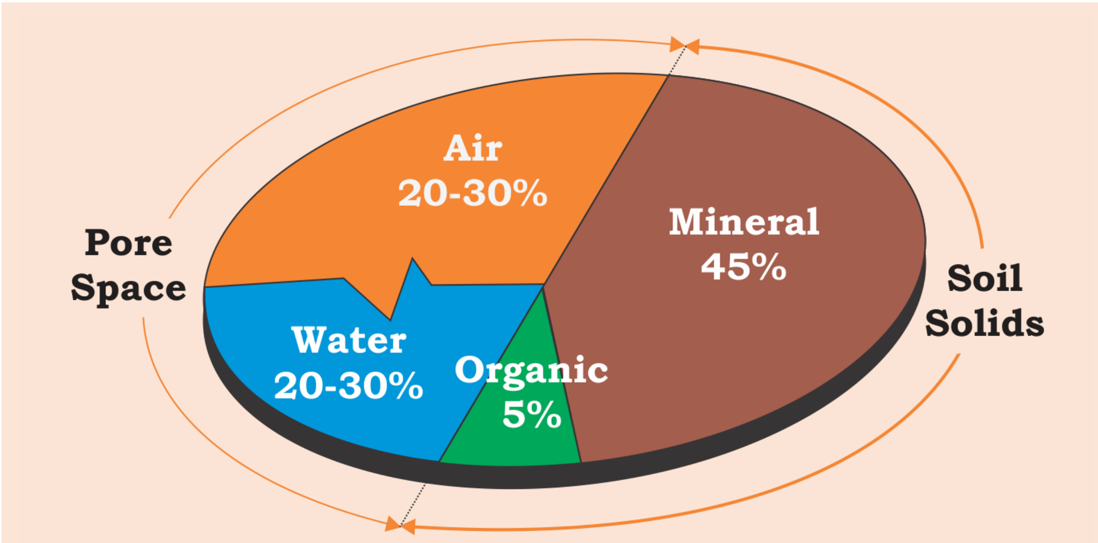


Fig. 1.4: Components of soil

The soil-air and water present in it create space in the soil. This soil space is occupied by about 50 % solids (mineral and organic matter) and the rest 50 % is empty space which is called the *'pore space'*. The pore space is interchangeably occupied by water or air. The figure above indicates that as the percentage of soil water increases, the percentage of soil air decreases and *vice versa*. The total solid space of the soil is occupied by 45% mineral matter and the remaining 5 % is the organic matter.

2.4 Properties of soil

Soils at a given location have distinct physical, chemical and biological properties. The detailed description of soil properties is given below:

2.4.1 Physical properties

Soil physical properties are essential for the movement of water, air, nutrients, and also for heat transmission. These properties are also responsible for providing better root anchorage to plants. Major soil physical properties include its color, texture, structure, moisture content, pore space, bulk density and aggregation shown in Fig.1.5.

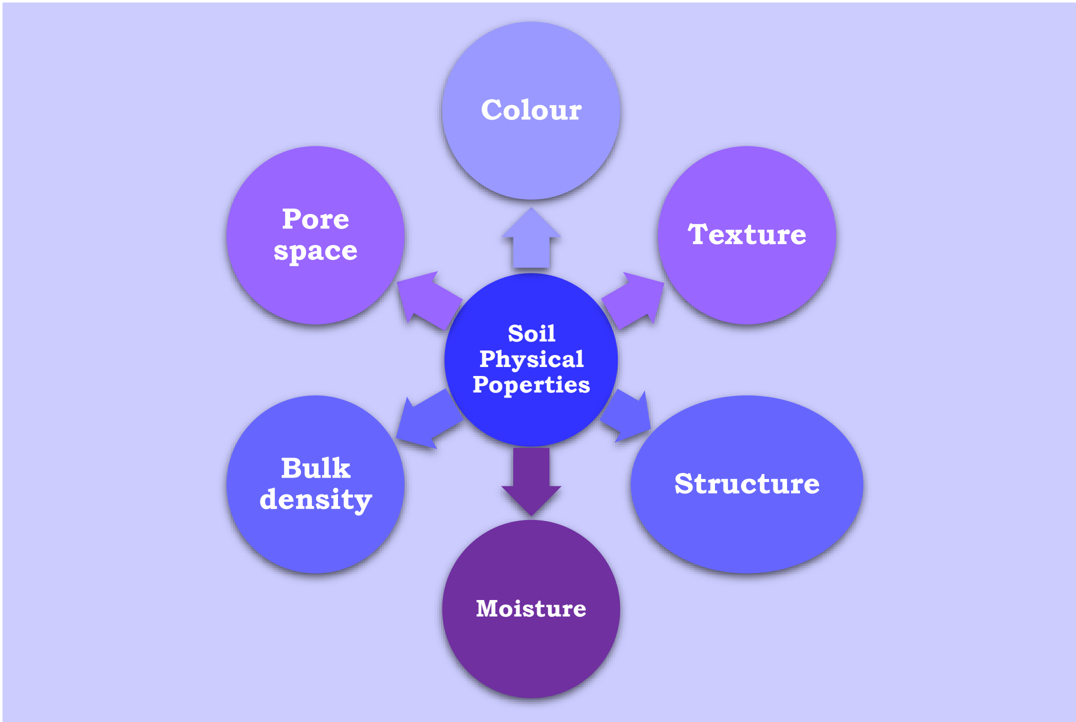


Fig. 1.5: Soil physical properties

Let us understand these properties one by one

i. Soil color

You must have noticed that, when you travel from one location to another location, you come across differently colored soils such as red soil, black soil, and brown soils (Fig.1.6).

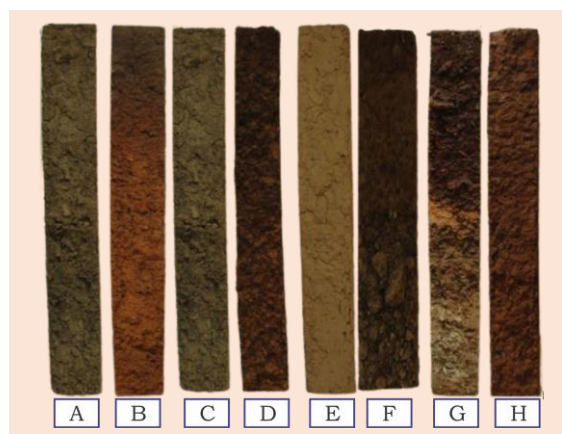


Fig 1.6: Eight different soil profiles (A to H) showing different colors)

Color is one of the easily observable features of soil. Soil color gives an indication about its different constituents such as clay content, organic matter and the presence of iron and aluminum oxides. For example, dark colored soil is generally linked with higher productivity due to presence of more organic matter.

Basic rocks form the dark-coloured soil, while acidic rocks result into light coloured soil. Red and yellow coloured soils are found under well drained conditions in tropical and sub-tropical regions.

(a) Determination of soil colour

A colour chart known as the "Munsell color chart", developed by Professor Albert H Munsell is widely used in the soil laboratories to determine the color of a given soil sample. According to Munsell colour chart, the soil colour is determined on the basis of its hue i.e. its colour wavelength, its value i.e. its color tone and chroma i.e. the colour saturation as shown in Fig.1.7.

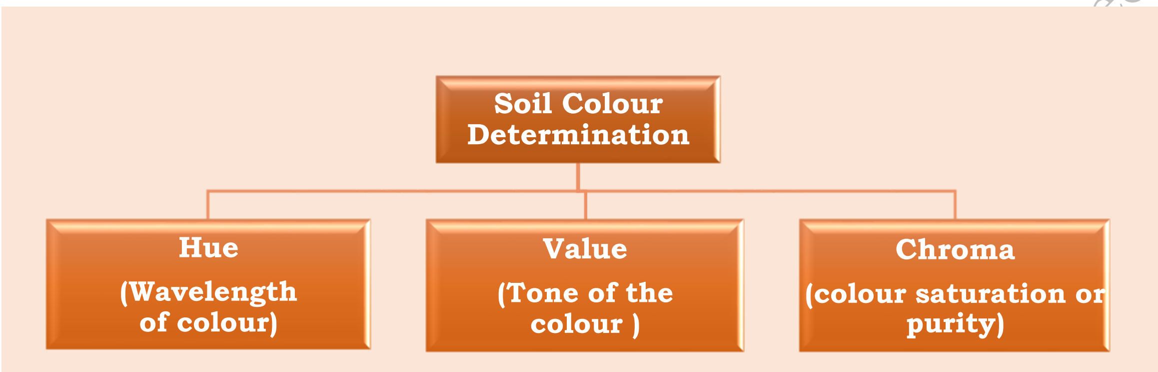


Fig. 1.7: Basis of soil color determination

(b) Important inferences drawn from soil color

By looking at the colour of a particular soil, different inferences about the productivity, climatic conditions of the soil or the region from where the sampling is done can be drawn as shown in Fig.1.8.

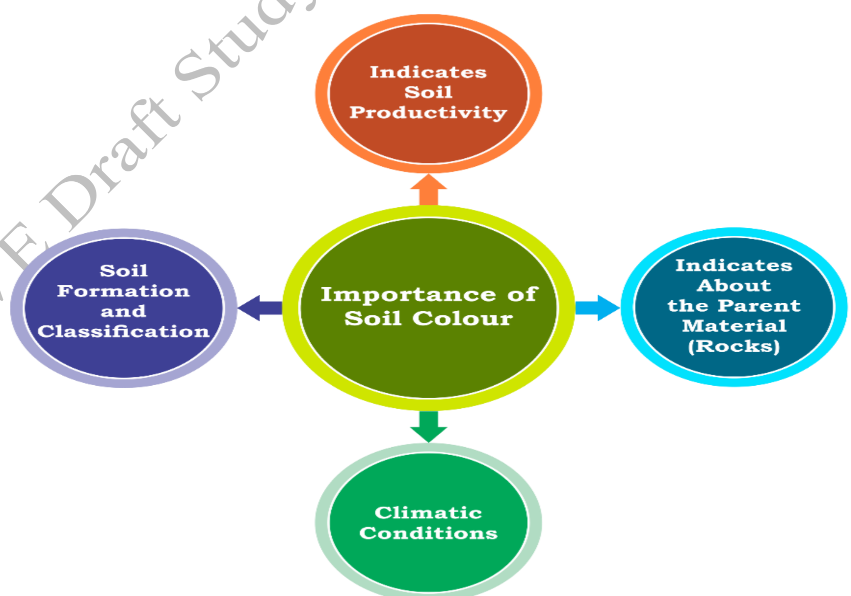


Fig. 1.8: Importance of soil colour

ii. Soil structure

The arrangement of the individual soil particles into large units is called soil structure formation (Fig.1.9). Soil structure is formed due to different arrangements amongst soil particles (sand, silt and clay) and organic matter. The relative content of sand, silt and clay in the soil determines its texture. Both the soil structure and its texture have a profound influence on the movement of water, nutrient and air in the soil. The units of soil structure are called Peds**.**

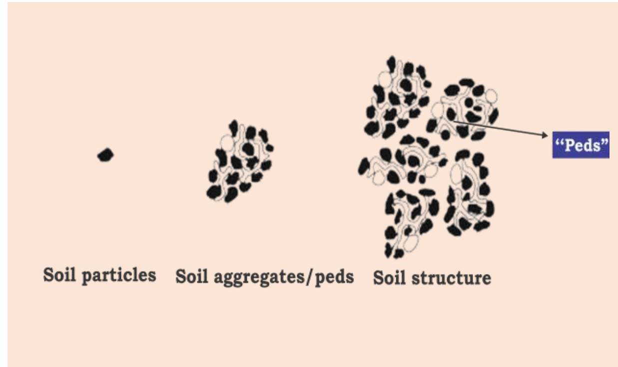


Fig. 1.9: Stages of formation of soil structure

Aggregation is the basic process through which soil particles bind in different patterns resulting in different soil structures. The principal binding agents for soil particles are clay, humus and calcium carbonate. The primary particle formed naturally in different forms and sizes due to this binding is called "peds". However, the soil aggregates formed due to agricultural practices like tillage and intercultural operations etc., are termed as "clods". Soil structure is usually described in terms of grade (i.e., degree of aggregation), class (i.e., average size of soil particle) and type of aggregation. Based on the type of soil aggregation, soil structures are grouped into crumby, granular, platy, blocky and prismatic etc. (Fig. 1.10).

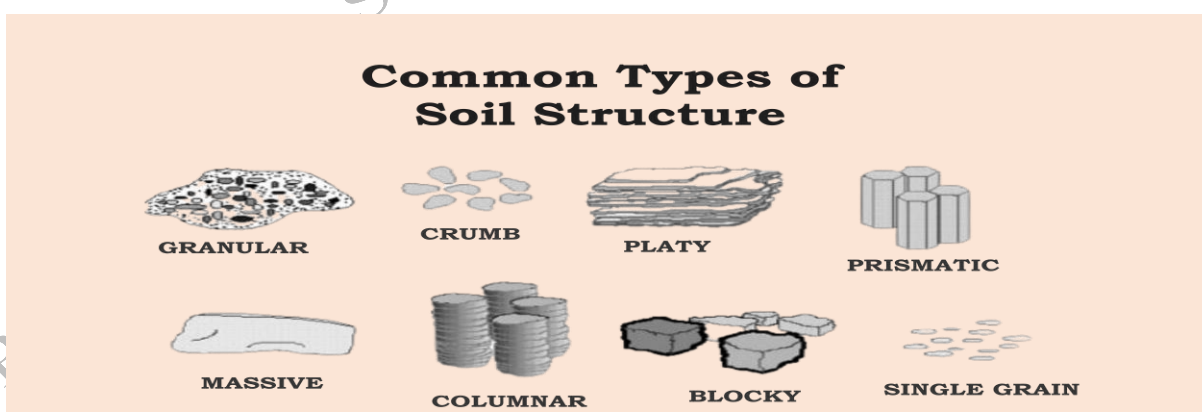


Fig. 1.10: Common types of soil structure

iii. Soil texture

Texture indicates how the soil feels to touch and indicates the relative content of particles of various sizes i.e., sand, silt and clay in the soil. Soil texture determines the pore space within it. Therefore, the soil texture influences the amount and movement of water, nutrients and air in soil.

a. **Size of primary particles**: The primary particles in soil are classified into sand, silt and clay. These are also called as 'soil separates' as shown in the table 1.3.

Table 1.3 : Particle Size of Different Soil Separates

Soil Primary Particles/soil separates	Size (mm) (International Standards)
Sand	2.00-0.02
Silt	0.02-0.002
Clay	<0.002

b. Determination of Soil Texture by Feel Method

Different feel methods are practised to determine the soil texture. Some of these methods are explained below.

Feel Method

1. Processing of soil step-I: Sieving of the soil sample (Fig.1.11).

1. Take air dried soil samples.
2. Sieve it through a 2mm sieve
3. The fine soil particles which pass through the sieve are used for the soil texture determination by feel method.

Step II: Take a handful of sieved soil and add water to moisten it. Now squeeze this moist soil into a ball. Two different tests to

Fig. 1.11: Sieving of soil samples

determine soil texture can be carried out with the moist soil ball as described below. A separate method called as the ribbon method is also described.

i. Throw ball test (figure 1.10 A-D)

1. Take a handful of moist soil and squeeze it into a ball.
2. Throw the ball into the air about 50 cm and then catch it.
3. If the ball falls apart, soil contains too much sand.
4. If the ball sticks together, soil contains enough clay.

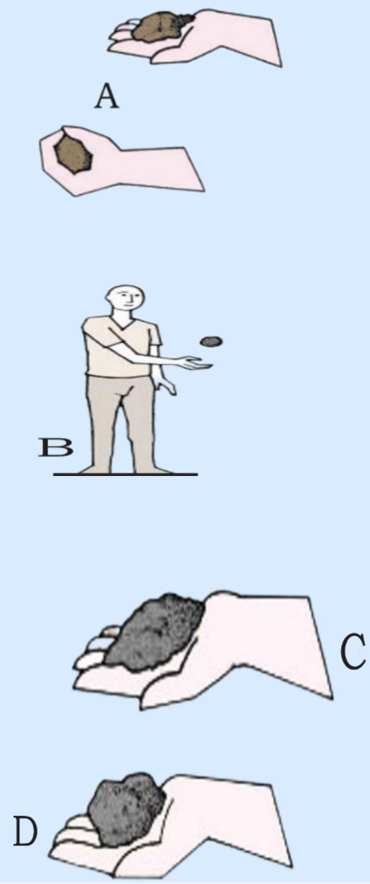
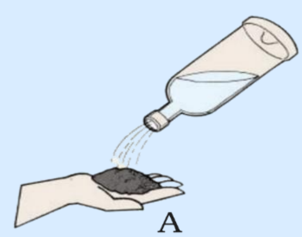


Fig. 1.12 (A-D): Throw ball test

ii. Squeeze the ball test (figure 1.13 A-D)

1. Take a handful of soil and wet it, so that it begins to stick together without sticking to your hand.



2. Squeeze it hard, then open your hand.

3. If the soil retains the shape of your hand, then the soil contains more clay.

4. If the soil does not retain the shape of your hand, then the soil contains more sand.

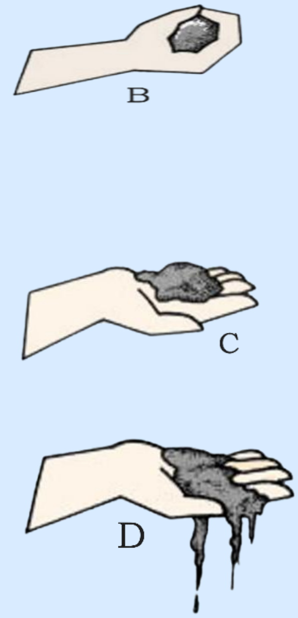


Fig. 1.13 (A-D): Squeeze ball test

Ribbon method (Fig.1.14)

1. Take a small quantity of soil and add water to moisten it.
2. Try to make ribbons from the moistened soil. The length of the ribbon formed determines the soil texture as explained below:
   - 15-25 mm -loamy soil
   - 25-40 mm- clay loam
   - 40-70 mm - clay soil
   - No ribbon formed –sandy soil

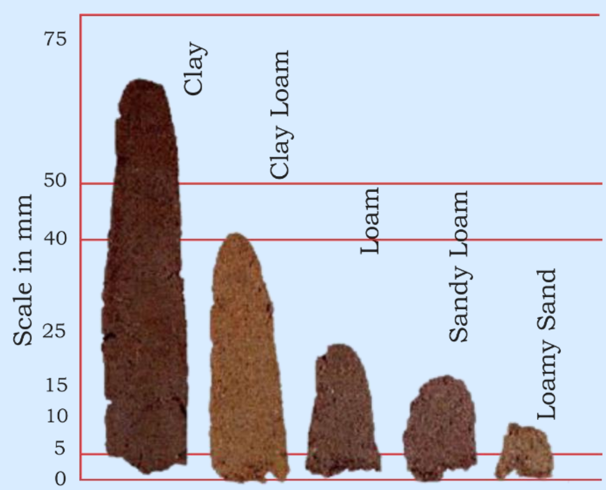


Fig. 1.14: Determination of soil texture by ribbon method

c. Method for determination of textural class of the soil

There are 12 different soil textural classes with varying content of soil particles or possible combination which can be displayed inside a triangle which used in different soil testing laboratories to determine the textural class to which the collected soil sample belongs. This is known as the Triangle method of soil texture determination.

This method contains the following steps:

Step 1: Determination of grain /particle size: Two different methods are used to find the texture of a soil sample in a laboratory i.e. (Fig.1.15):

a. international pipette method: The method is based on the principle of sedimentation. In sedimentation the suspended material such as clay or silt settles by gravity. To determine soil texture, a suspension of soil in water is made. This sample is pipetted out at different time-intervals and at different depths from the suspension in a measuring cylinder. The pipetted suspension is dried, condensed and the percentage of soil particles settled is determined.

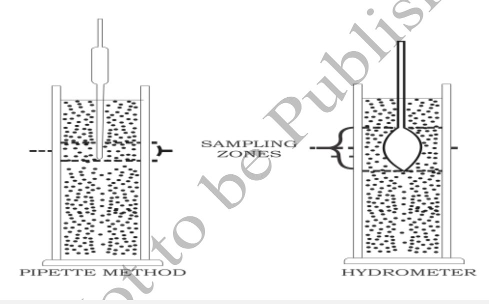


Fig.1.15: Determination of soil texture by pipette method and hydrometer method

b. Bouyoucos hydrometer method: This method is also based on the principle of sedimentation. The soil solution is poured into a tall cylinder fitted with a hydrometer.

The hydrometer reading is noted at 40 seconds. Subsequently reading for silt is noted after one hour and the reading for clay is noted after 2 hours.

Step 2: Determination of soil textural class

You can find out the soil textural class by drawing appropriate lines on the textural triangle (Fig.1.16) and the intersection point gives you the soil texture.

For example, if clay percentage is about 60% then draw line parallel to sand. If the sand component is about 20%, then draw a line parallel to silt. Likewise, if silt component is 20% then draw a line parallel to sand. Following are some examples of soil textural class determination:

1. 60% sand, 25% silt, and 15% clay = Sandy loam

2. 20% sand, 20% silt and 60% clay = Clay

3. 25% sand, 45% silt and 30% clay = Clay loam

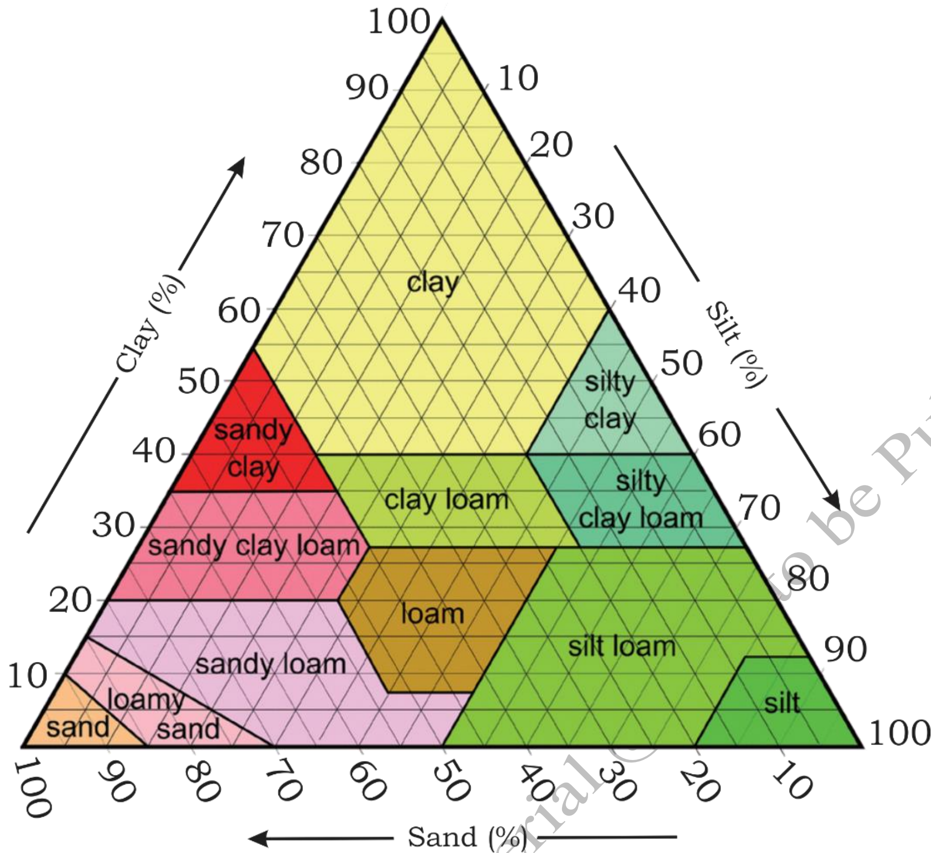


Fig. 1.16: Textural triangular diagram for soil texture determination

iv. Soil bulk density and particle density

Bulk density is one of the important soil physical indicators and provides information about soil compaction and root growth development. It reflects the size, shape and arrangement of the soil particles and the pore space. Bulk density is expressed as dry weight of soil divided by total volume of soil. The total volume includes the volume of soil particles and the volume of pores among soil particles. Particle density is the mass of soil solid divided by volume of soil solid alone.

Therefore,

Bulk density = mass of soil solids / total volume of soil.

A fertile soil has one-half of solids, and another one-half of pore space. Therefore, a 1 cm^3 volume of fertile soil would have 0.5 cm^3 of pore space and 0.5 cm^3 of solids.

The weight of the air in the pore space is considered 0 g (Nil). The particle density of soil is assumed to be 2.66 g/cm^3. Organic matter is a very small portion of the solids, and usually ignored in calculating bulk density. Therefore, the mineral solids in the soil sample would weigh 1.33 g when dry, and is determined by multiplying particle density by the volume of solids as is shown below:

$$2.66 \text{ g/cm}^3 \times 0.5 \text{ cm}^3 = 1.33 \text{ g}$$

Thus, the bulk density is the dry weight of soil divided by the volume of soil:

$$1.33 \text{ g} / 1 \text{ cm}^3 = 1.33 \text{ g/cm}^3$$

Increasing bulk density signifies an increased per cent solid and a corresponding decrease in per cent pore space.

An example of calculating pore space and bulk density of a given soil sample.

% solid= Bulk density/Particle density x 100

and % pore space = 100 – % Solid

These two equations can be combined into one

% 100 – bulk density/particle density x 100

Or

$$\% \text{ pore space} = \left[1 - \frac{\text{bulk density}}{\text{particle density}}\right] \times 100$$

If soil with bulk density of 1.1 g/cm^3 and a particle density of 2.65 g/cm^3 then pore space is calculated as:

If we know the bulk density (BD) and particle density (PD) of soil, we can calculate pore space of a given soil sample. For this first we determine the BD by weighing a soil sample of measured volume. The PD is assumed to be 2.65 g/cm^3

$$\left[1 - \frac{1.1}{2.65}\right] \times 100 = 59\% \text{ pore space}$$

Therefore, solids are 100-59% = 41% solid

Density of soil varies with the texture, which directly influences the pore space. The relationship of different textural classes with bulk density and pore space is given in the Table 1.4.

Table 1.4: Relationship of Different Textural Classes With Bulk Density and Pore Space

Textural class	Bulk density (g/ cm³)	Pore space (%)
Sandy soil	1.6	40
Loam	1.4	47
Silt loam	1.3	50
Clay	1.1	58

v. Soil aggregation

Primary soil particles of sand, silt and clay are united together to form secondary soil particles which are called soil aggregates or peds.

Aggregate stability is an important indicator of soil physical quality. Soils with stable aggregates at the surface are more resistant to water erosion than other soils with unstable aggregates which disperse frequently during rains and storms and form a hard physical crust when the soil dries.

Stability of soil aggregates is assessed by their ability to remain intact when subjected to a given stress like wind and water erosions. Soil aggregates are classified as: clay-aggregate (< 2 µm), micro-aggregate (2-250 µm), and macro-aggregate (> 250 µm) units.

2.5. Moisture content of soil

The moisture content of soil indicates the amount of water present in it. It is expressed as the amount of water per unit mass or volume of the soil. ***For example:*** When 150 mm of water is present in a depth of one-meter-deep soil, the soil moisture content is 150 mm/m (figure1.17). This is moisture content expressed in volumetric terms. The soil moisture content can also be expressed in weight-by-weight basis.

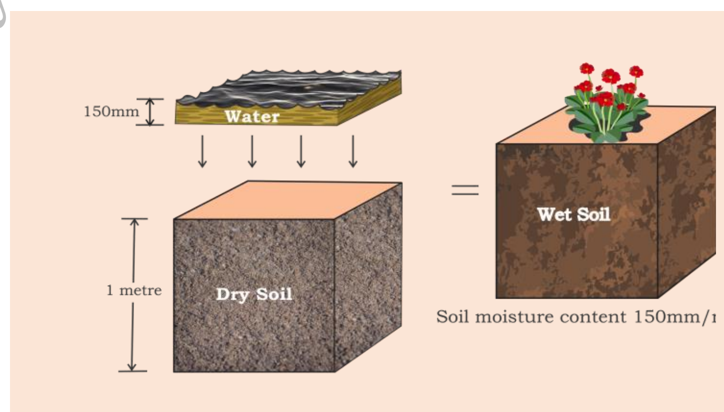


Fig. 1.17: Soil moisture content of 150 mm/m

Solved example: Suppose in $1m^3$ of soil (e.g., with a depth of 1 m, and a surface area of 1 m^2) there is 0.150 m^3 of water (e.g., with a depth of 150 mm = 0.150 m and a surface area of 1 m^2)

Then, soil moisture content in volume percent is:

$$\frac{0.150\text{m}^3}{1\text{m}^3} \text{x}\, 100 = 15\%$$

Similarly, the moisture content of 200 mm/m corresponds to a moisture content of 20 percent on volume basis.

Moisture retention capacity of a soil is denoted in terms of three moisture equivalents *viz.*, saturation, field capacity (FC) and permanent wilting point (PWP). Soil moisture retention plays a significant role in plant growth.

2.5.1 Saturation

Due to prolonged rain fall or heavy irrigation, all the soil pores are filled with water (Fig 1.18A). Such soils are said to be saturated i.e., at maximum water holding capacity. No air is left in the soil at saturation point. Many crops cannot withstand prolonged saturated conditions with the exception of rice. In sandy soils, excess water is drained off within a period of a few hours whereas clayey soils need 2-4 days to drain off the excess water.

2.5.2 Field capacity

After the drainage of excess water, the rate of downward movement of water decreases. The larger soil pores are still filled with both air and water while the smaller pores are still full of water (Fig 1.18 B). At this stage, the soil is said to be at its field capacity (FC). At field capacity, the water and air contents of the soil are considered ideal for crop growth.

The time needed to reach field capacity in a soil is affected by its texture. The field capacity in sandy soils is reached in 1-2 days, and in clayey soils it takes about a weak. The volumetric soil moisture content retained at field capacity is about 10 to 18% for sandy soils, 20 to 32% for loam soils, and 36 to 42% for clay soils.

2.5.3 Permanent wilting point

After the soil has reached its field capacity, the water content present in the soil is used up gradually by the process of evapotranspiration. If there are no further rains or irrigations, the soil reaches its permanent wilting point where the plants start to wilt. If this stage still continues for more time then the plant may die and this stage is called Permanent Wilting Point (PWP). The permanent wilting point is depicted in the figure 1.18 C. The moisture held ≥ 31 atm or bar is called as hygroscopic water.

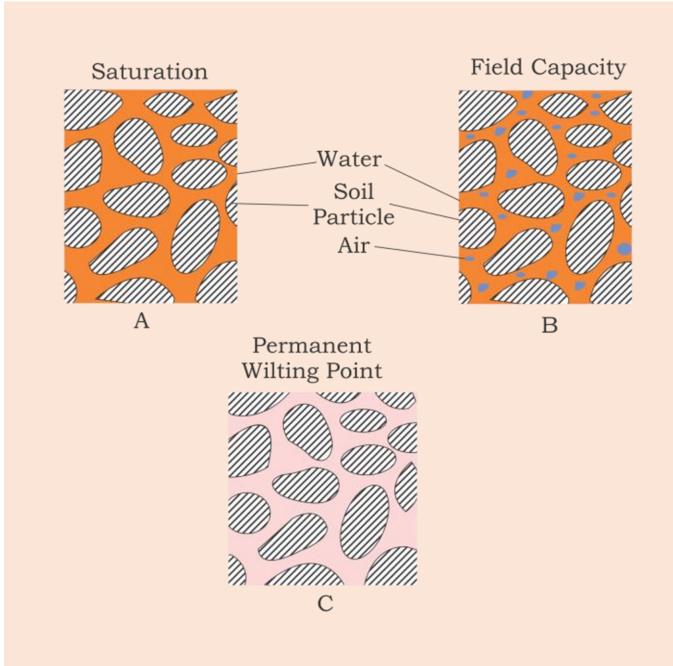


Fig.1.18: Soil water content at

A. saturation B. field capacity C. permanent wilting point

Activities

Activity 1: Find out the soil texture class of soil by drawing lines in triangular diagram (refer figure 1.14)

Requirement: Textural triangle diagram, Pen, Paper

Procedure: Find out the soil texture.

For example:

If the clay percentage is 50% then draw line parallel to sand;

If sand is 20% draw a line parallel to silt, likewise, and the intersection point gives you the soil texture in the triangle

30% sand, 20% silt, and 50% clay

Answer: Clay texture

Activity 2: Go to the garden and collect soil samples in polybags with the help of a gardening tool like a khurpi or hand trowel. Bring them to the laboratory and with the help of feel method taught in the class find out the soil texture.

Requirements: Soil samples, 2mm sieve, water for moistening the soil sample.

Procedure:

1. Go to the garden and collect soil samples from different places in air tight polybags.
2. Bring them to the laboratory and sieve them with the help of a 2mm sieve.
3. Moisten the sieved soil to make ball out of it.
4. As per the lesson taught in your class, determine the texture of this soil. (Hint: refer to section…)

Activity 3: Observe the colour of the soil in your locality and draw your inferences based on the lesson taught in the class.

Requirements: Soil samples collected around your locality, polybags.

Procedure: Observe the colour of the collected soil samples and draw your conclusions based on the lessons taught in the class. (Hint : refer section :)

Activity 4: Determination of saturation point of differently textured soils.

Requiremets: Soil samples of different textures, glass cylinders (100ml), water, pen, notebook.

Procedure:

1. Collect 20 g of soil samples of different texture
2. Fill them in different glass cylinders of 100ml capacity
3. Now add water to them dropwise.
4. Observe the quantity(volume) of water needed to saturate the soil. Observe whether the required volume of water to saturate different textured soil is same or not. List out your conclusions with reasons.

Check Your Progress

Multiple Choice Questions

1. After drainage of excess water in soil, larger soil pores are filled with both air and water while the smaller pores are full of water, this stage is known as
   a) Moisture retention
   b) Field capacity
   c) Permanent wilting point
   d) Saturation

2. Soil physical properties are essential for
   a) Water and nutrient movement,
   b) Air and heat movement in soil
   c) Provide better root anchorage to plants
   d) All of the above
3. Major soil physical properties include
   a) Color, texture and structure
   b) Moisture content and pore space
   c) Bulk density and aggregation
   d) All the above
4. The moisture content in soil at which plants start to wilt and ultimately die is called
   a) Moisture retention
   b) Field capacity
   c) Permanent wilting point
   d) Saturation
5. Soils are formed from rocks and minerals by
   a) Chemical weathering
   b) Physical weathering
   c) Biological weathering
   d) All of the above

Fill in the Blanks

1. Ribbon method is a kind of ....method used to determine the soil texture.
2. Arrangement of the individual soil particles into large units is called ....
3. Naturally occurring aggregates are called ....
4. Relative per cent of various sizes particles such as sand, silt and clay in the soil is called ....
5. .... is the weight of soil solids per unit volume of total soil.

True or False

1. Generally, clay particles have >0.002 mm size
2. Soil is not a dynamic natural body and it takes only few years to form one inch of soil.
3. Different soils have same physical, chemical and biological properties.
4. Generally, soils contain 45% organic matter.
5. Soils at a given location don't have distinct physical, chemical and biological properties.
6. Generally, clay, humus and calcium carbonate act as binding agents for soil particles.

Session 3: Chemical Properties of Soil

Soils have distinct chemical properties which play an important role in plant nutrition. In this session we will discuss some of the chemical properties such as soil pH, electrical conductivity, soil organic carbon and available nutrients.

3.1 Soil pH

Soil pH is a measure of the acidity or alkalinity of the soil. pH is defined as the negative (-) logarithm of active hydrogen ions (H^+) concentration. As hydrogen ion concentration varies over a wide range, a logarithmic scale is used in pH measurement. For example, as the pH decreases from 6 to 5 then acidity increases by a factor of 10. (Note: log 10 = 1)

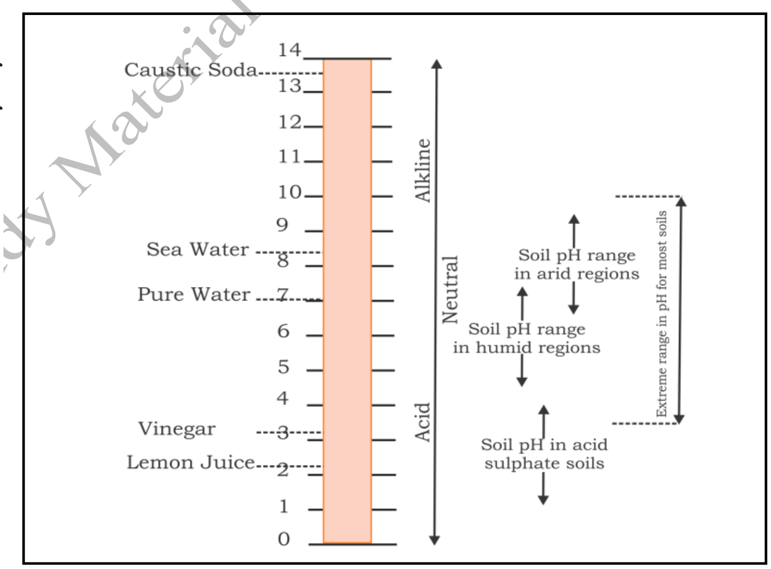


Fig. 1.19: pH scale

pH scale ranges from 0 to 14 with pH 7 as the neutral point. Soil pH varies with the presence of hydrogen (H+) and hydroxyl ions (OH^-). As the amount of hydrogen ion concentration increases, the soil becomes more acidic whereas, if hydroxyl ions (OH)

Do you know!

- Pure water such as rain water is close to a neutral pH (7.0)
- Sea water has a pH more than 8.0

concentration increases the pH increases above 7 and the soil solution becomes alkaline (Fig. 1.19).

Soil pH is one of the most important factors in plant growth as it influences nutrient availability, toxicity in plants and the activity of organisms in soil.

Most of the essential nutrients for plants are available in the range of pH 6.5 - 7.5 which is measured with the help of an instrument known as the soil pH meter (Details description is presented in Module 3).

3.2 Electrical conductivity

Soils contain various types of salts. For example, salts of calcium, sodium and potassium. These salts can be sulphates, chlorides, carbonates or bicarbonates and have a direct influence on seed germination, root growth and uptake of nutrients in plants. Excess of these salts adversely affect the plant nutrient availability, crop yields, crop suitability and activity of soil microorganisms. The amount of salts present in soil is measured as electrical conductivity (EC). The details of measurement of EC are given in Module 3.

Do you know!

- Soil salinity is developed due to poor quality irrigation water, sea water intrusion in coastal areas, excess use of chemical fertilizer and canal water.
- Soils with a high concentration of sodium salts have problems such as poor soil structure, poor infiltration or drainage, and toxicity for many crops.
- Electrical conductivity is affected by various factors such as irrigation, land use, application of fertilizer, manure,

2.3 Available nutrients

Soil contains many essential plant nutrients but all of them are not available to plants. These essential elements are present in soil either as soluble (ionic) or insoluble (fixed or complex) form. The available nutrients are usually much less than the total amount of nutrient present in the soil. Only the elements or nutrients in soluble form are readily available to the plants. Such forms of nutrients are the *available nutrients*. Most nutrients are optimally available to plants within the 6.5 to 7.5 pH range. This pH range is also considered very suitable for root growth A detailed description of it is given in Module 2.

3.3.1 Factors affecting nutrient availability

The different factors affecting availability of the soil nutrient is shown in Fig.1.20.

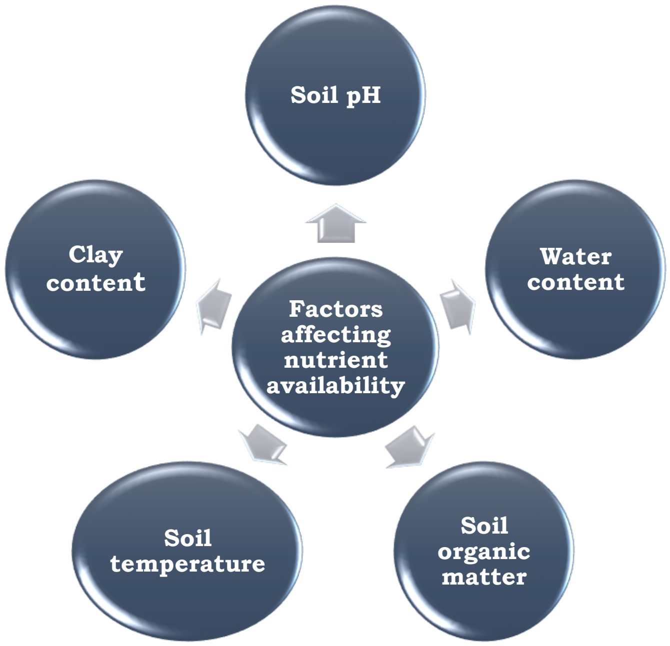


Fig. 1.20: Factors affecting soil nutrient availability

Activities

Determine the pH and the presence of carbonates and bicarbonates in differently coloured soil samples.

(Hint: effervescence indicates the presence of carbonates and bicarbonates.)

Requirements: pH paper/ Litmus paper, 50 ml beakers, water, watch glass or small glass beakers (50 ml), hydrogen peroxide.

Procedure:

1. Collect differently colored soil samples and assess the pH using pH paper/Litmus paper (available in your laboratory).
2. Assess the pH using pH paper/Litmus paper after making suspensions of small sub samples in a 50ml beaker.
3. Record your observations

4. Now, to each sample add a few drops of Hydrogen Peroxide, observe if effervescence is produced or not.
5. Based on your observations, draw conclusions and record them.
6. Now, to each sample add dil. HCl (1:1 ratio). Observe if effervescence is produced or not.
7. Discuss amongst yourselves in the class room.

Check Your Progress

Multiple Choice Questions

1. Measurement of hydrogen ion activity in terms of acidity or alkalinity of the soil is known as
   a) Soil acidity
   b) Alkalinity
   c) Soil pH
   d) Salinity
2. Most plant nutrients are optimally available to plants within the soil pH range of
   a) 6.5 to 7.5
   b) 5.5 to 6.5
   c) 4.5 to 5.5
   d) 7.5 to 8.5
3. Pure water such as rain water is close to a neutral pH
   a) 6.0
   b) 7.0
   c) 8.0
   d) 9.0
4. The soil salinity is measured in terms of
   a) Soil acidity
   b) Electrical conductivity (EC)
   c) Soil pH
   d) None of the above

5. Essential elements are present in soil as
   - a) Soluble (ionic) form
   - b) Insoluble (fixed or complex) form
   - c) Both
   - d) None of the above

Fill in the Blanks

1. Soils contain various types of salts such as salts of -------, ---------and -------------
2. Elements or nutrients present in soluble form in soil which are readily available to plants are called--------------
3. -------------- pH range is considered very suitable to plant root growth
4. -------------- instrument is used to measure soil pH
5. -------------- instrument is used to measure electrical conductivity

True or False

1. pH scale ranges from 0 to 14 with pH 7 as the neutral point
2. Sea water has a pH less than 8.0
3. Soil pH varies with the presence of hydrogen (H+) and hydroxyl ions (OH-).
4. Soil pH plays significant role in plant growth and nutrient availability
5. Soils with a high concentration of sodium salts do not pose the problems of poor soil structure, poor infiltration and toxicity for many crops

Session 4: Biological Properties of Soil

In this session we are going to learn about the biological properties of soil. A teaspoon of soil generally contains millions of microorganisms. That is why soil is considered as a living entity. These microorganisms govern the biological properties of soil. They perform numerous functions for their growth and reproduction inside the soil. These functions directly or indirectly influence the availability of nutrients to the plants. Soil organisms play important role in determining many soil characteristics such as decomposition of organic matter, nutrient availability, soil fertility, and plant growth

4.1 Soil microflora

Soil biological properties include flora and fauna activity. Most of the soil biological activities occur in surface soils (0-15 cm). Majority of the soil organisms are not visible to naked eyes and can be seen through microscope (microorganisms) whereas certain others which are larger in size are visible to naked eyes. Organisms such as ant, earthworms, snails and rodents have significant effect on soil properties due to churning and mixing of soils brought about by their movement in the soil. 'Soil biota' is a collective term that comprises all organisms present in the soil.

4.1.1 Classification of soil organisms

A. Soil organisms can be classified on the following basis:

(i) Soil flora i.e., soil organisms belonging to plant kingdom

(ii) Soil fauna i.e., soil organisms belonging to animal kingdom.

B. They are also classified depending on their size,

(i) Macroorganisms can be seen easily by unaided eye

(ii) Microorganisms visible only with the help of microscope. Fig. 1.21 gives the classification of soil organisms.

C. Soil organisms can also be taxonomically classified (kingdom to species) as presented in the figure 1.22

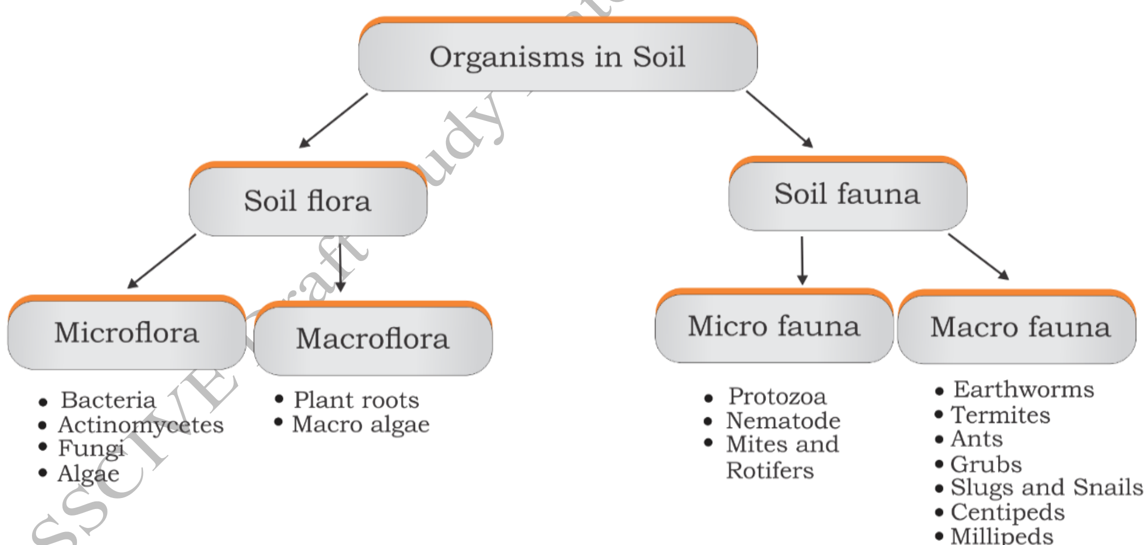


Fig. 1.21: Classification of soil organisms

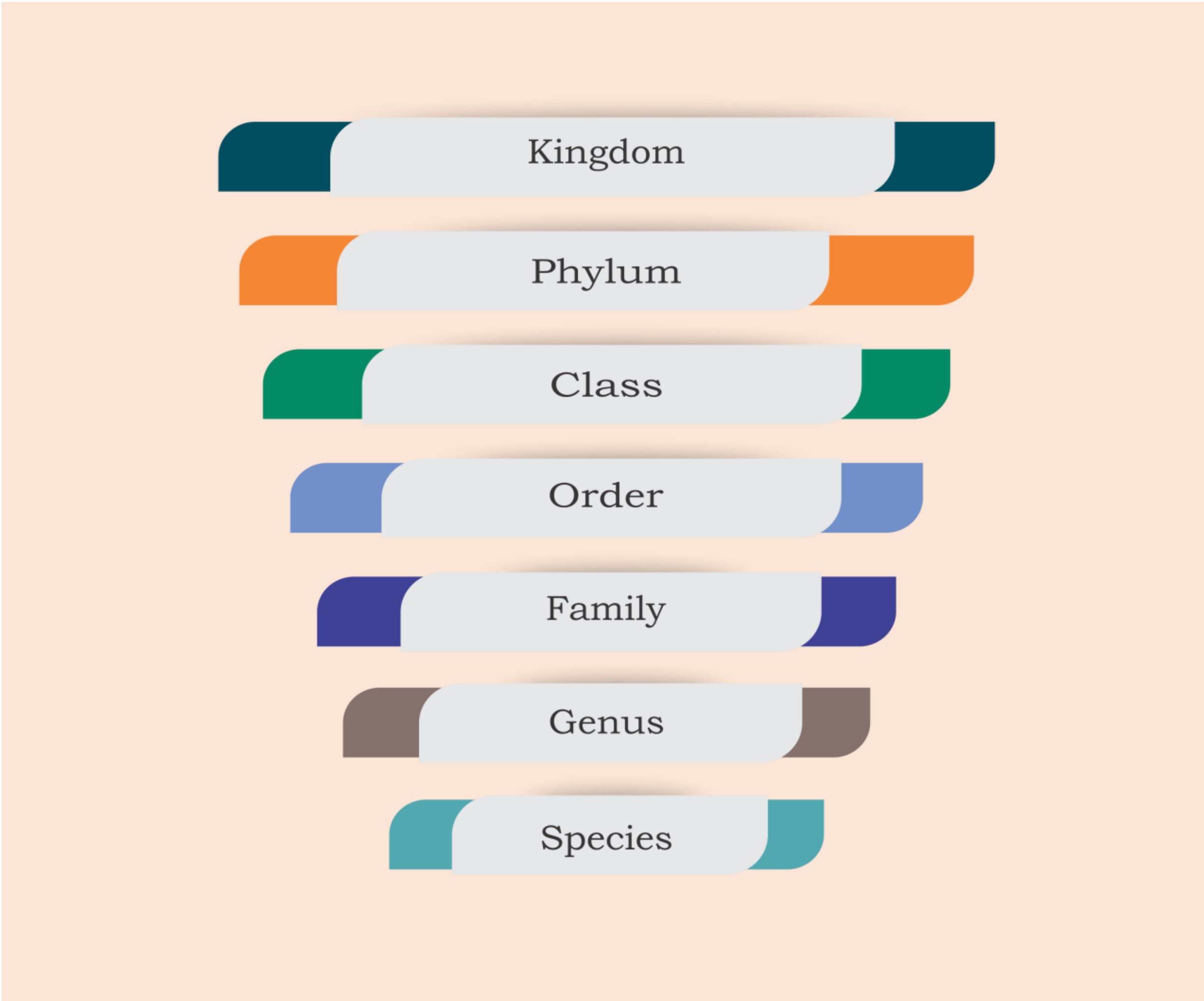


Fig. 1.22: Taxonomical classification

4.3 Functions of soil micro-organisms

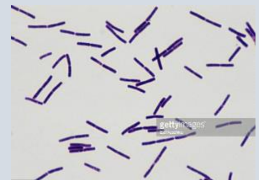
Soil microorganisms play a variety of roles which are shown in Fig.1.23.

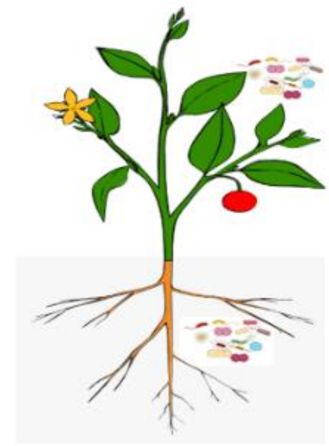
Fig. 1.23: Role of soil microorganisms

4.4 Common organisms found in the soil

Detailed descriptions of some of the most common soil organisms including their taxonomic classification, size, major functions and images (1.24 a-d, 1.25 a-d, 1.26 a-h, 1.27 a-c) are given in table 1.5.

Table 1.5: Some Common Soil Organisms and Their Description

Soil organism	Taxonomic class	Size	Major function	Image
Soil microflora (Fig. 1.24 a-d)				
Bacteria	Prokaryotes (devoid of nucleus, Golgi apparatus, etc.)	Diameter: 1 µm Length: 10 µm.	Organic matter decomposition, nutrient availability to the plants.	 ***a. Bacterial cells***
Fungi	Eukaryotes (have nucleus, Golgi apparatus, etc.)	2 to 10 µm in diameter fungal hyphae.	Organic matter decomposition, hyphae can move to deeper soil for nutrient transfer to plant.	 ***b. Fungi***
Actinomycetes	Prokaryotes	0.5 to 1.2 micron (µ).	Soil organic matter decomposition, Maintain biological equilibrium in soil.	 ***c. Actinomycetes***
Algae	Prokaryotic or eukaryotic.	2-5 µ in diameter.	Organic matter decomposition, Soil structure improvement, increase nutrient availability.	 ***d. Algae***

Soil macroflora (Fig. 1.25 a-d)				
Plant roots	Plantae	Very fine roots: <2 mm Thick roots >2 mm to several cm.	Roots and its surrounding are called rhizospheres which provides foods (soluble carbohydrates, root exudates) for soil dwelling microbes, Improves soil aeration and improves the organic matter status of soil.	 ***a. Plant roots (Rhizosphere)***
Lichen and moss	Prokaryotic or eukaryotic.	100 µm to more than 3mm	They secrete different organic acids that help in weathering of rock and minerals and also prevent soil erosion.	 ***b. Lichen***  ***c. Moss***
Macro algae	Eukaryotes	Unicellular forms can be up to 50 mm in di ameter.	Primary producers of organic matter, help in aggregate formation, prevent soil erosion.	 ***d. Macro algae***

			Example: Blue green algae (cyanobacteria).	

Soil Macrofauna (Fig. 1.26 a-h)				
Earthworm	Annelida	10-25 cm long.	Decomposition of organic matter or farm waste (vermicompost) intimate mixing of organic matter with mineral component of soil, make the soil more porous, increase availability of nutrients Degrade large fraction of organic waste to smaller particle that influences the activity of other microorganism activity.	 ***a. Earthworm*** Major species found in the soil are *Eisenia foetida,* *Eudrilus eugeniae* *Perionyx excavates*
Termite	Isoptera	0.5-2.5cm long.	Physical modification of soil structure, changes the nature and	 ***b. Termite***

			distribution of organic matter.	
Grubs	Hexapoda	2.5-3.5 cm long.	Feed on organic matter in soil as well as the root system of many economic crops.	 c. Grubs
Ants	Insecta	0.75-52 mm.	Turn and aerate the soil, allowing water and oxygen to reach plant roots.	 d. Ants
Centipedes	Chilopoda	About 30 cm.	Feed on mostly Decaying vegetation Burrow the soil and aerate the soil.	 e. Centipedes
Snails	Gastropoda	Largest species is upto 40 cm.	Feed on the decaying vegetation but also damages living materials.	 f. Snails
Slugs	Gastropoda	13 to 38 mm and some species about 10 cm.	Feed on the decaying vegetation but also damages living materials.	 g. Slugs

Millipedes	Diplopoda	1.4 mm to 30 cm.	Natural decomposer, recycle nutrients and aerate soils.	 ***h. Millipedes***
Soil microfauna (Fig. 1.27 a-c)				
Protozoa	Protista	20–80 mm.	Important functions in the decomposer cycle and plant growth.	 ***a. Protozoa***
Nematodes	Animalia	50 µm.	Decaying organic matter, some prey on soil microorganims and some may be parasitic causing plant disease.	 ***b. Nematoda***
Mites	Arachnida	200 to 1,400 µm.	Feed on fungi and nematodes and are extremely important in maintaining soil health and fertility.	 ***c. Mites***

Biofertilizers

Biofertilizer can be defined as biologically active products containing living microorganisms on a suitable carrier used to inoculate seed, plant surfaces, or soil, promote growth by several mechanisms such as increasing the supply of nutrients, increasing root biomass or root area and increasing nutrient uptake capacity of the plant. Use of biofertilizers helps in mobilizing plant nutrients by microbial activity contained in it.

There are mainly of two types of biofertilizers such as

(i) Nitrogen fixing biofertilizers (NBF) – its role mainly to reducing atmospheric nitrogen.

(ii) Phosphatic biofertilizers which contain live cells of phosphate solubilizing microbes belonging to the genera Pseudomonas and Bacilllus (Bacteria), fungi like Penicillum and Aspergillus (fungi)

(iii) VAM (vesicular arbuscular mycorrhiza) : An association of fungi and roots of higher plants. There are other types of biofertilizer which is used in agriculture depending on the various purposes as listed int the table

Commonly used biofertilizers: Some of the commonly used biofertilizers along with their application and examples are given in table 1.6.

Table 1.6: Common Biofertilizers and Their Application

Types	**Examples**	**Application**
Nitrogen fixing biofertilizers	Rhizobium (Symbiotic)	It is crop specific and used to inoculate leguminous crops such as soybean, Pegeon pea, lentil etc.
	Azospirillum (Associative)	It is not crop specific and associated with roots of cereal crops like maize, rice, wheat.
	Azotobacter (free living or non-symbiotic)	Non-symbiotic N-fixers and it is used for inoculating a wide range of crops
Phosphatic biofertiliers	*Bacillus megaterium* var. *phosphaticum, Bacillus subtilis B. circulans, Pseudomonas striata* (Bacteria) Penicilium sps and Aspergillus *awamori* (Fungi)	Soil application for all crops

VAM (Vesicular arbuscular mycorrhizae)	Glomas mosseae, Gigaspora margarita, *Acaulospora sp.*, *Scutellospora sp.* & *Sclerocystis sp.* (plant symbiosis)	Many trees, some crops (tomato, groundnut etc).
Cyanobacteria (Blue Green Algae, BGA) and Azolla.	*Anabaena, Nostoc (free living), Anabaena azollae (symbiotic)*	Rice/wet lands
Bio-control against pathogenic fungi	Trichoderma (fungi)	It is effective against many pathogenic fungi i.e. Fusarium, Rhizoctonia, Pythium, Schlerotinia, Verticillium, Alternaria, Phytopthrora and other fungi

Activities

Take a handful of soil from nearby field/garden and observe the different micro- and macro-fauna with the help of a microscope. Make a list of them and discuss it in your class.

Requirements: Soil sample, observation note book, pen, microscope.

Step by step process:

1. Go to a field/garden
2. Collect soil samples
3. Observe these samples under a microscope with the help of your teacher
4. Make a note of your observations and discuss it with your teacher.

Check Your Progress

Multiple Choice Questions

1. Soil biota is the collective terms for
   a) All organism presents in soil
   b) All microorganism only
   c) All earthworm species only

d) None of the above

2. Protozoa is soil belongs to

a) Macrofauna

b) Microfauna

c) Microflora

d) Macroflora

3. Primary role of soil organisms is

a) Organic matter decomposition

b) Nutrient cycling

c) Maintenance of soil acidity

d) Biological nitrogen fixation

4. The region around plant roots is also called as

a) Rhizosphere

b) Phyllo sphere

c) Biosphere

d) None of the above

5. Algae present in soils help in

a) Aggregate formation

b) Reduce soil erosion

c) Organic matter decomposition

d) All of the above

Fill in the Blanks

1. The compost formed through earthworm is called ……
2. Nematode generally eat ……. in the soil
3. Plant roots produce some organic substances which are called………
4. Most commonly occurring species of earthworms in soil is ………
5. Fungi has…………to move deeper into the soil

True or False

1. A teaspoon of soil generally contains few microorganisms.
2. Most of the soil biological activities occur in deeper layers of soil (beyond 15 cm).
3. Microorganisms are visible with the help of microscope.
4. Termites in the soil improve soil aeration.
5. Earthworm is an example of micro fauna.

Session 5: Soils of India

You must have studied that animals and plants have been scientifically classified into different kingdom to species. Similarly, all the soil in the world is also classified into different Orders (12), Suborders (63), Great Groups (319), Subgroups (2484), Families (~8000), and Series (~19000). This classification provides a means of communication among the persons working in the area of soil science and research. The description of the twelve soil orders and their characteristics are shown in table 6.

5.1 Major types of soil and their characteristics

India has a geographical area of 329 Mha. Large variations are observed in Indian soils due to diverse climate and diverse parent materials spread over the country. India has all the major soil orders present in the world except Andisols and Spodosols (Table 7). The description of major types of soils found in India is given below and also shown in figure 1.28.

5.1.1 Alluvial soil

Amongst all the countries in the world, India has one of the largest shares of alluvial soil which supports the food needs of more than 40% of Indian population. Such soils cover around 34% of total geographical area and have the highest productivity as compared to all other soil types. These soils are present mostly along the river sides. Alluvial soils are predominantly found in the Indo-Gangetic plains as well as on the banks of major rivers in India. These soils fit in the orders of Entisols, Inceptisols, Alfisols and Aridisols.

5.1.2 Black soils

These soils cover about 17 % of total geographical area in the country. Predominantly found in Maharashtra, Madhya Pradesh, Gujarat, and some parts of Andhra Pradesh, Karnataka, and Tamil Nadu. These soils are locally known as *Regur, Karail, Bhal and Tals.* They are also popularly known as black cotton soils. Due to the high clay (30 to 80%) content found in them, these soils retain more water. Such soils become sticky when wet and develop deep wide cracks when dry. The cracks permit oxygenation of the soil to sufficient depths increasing their fertility in an extraordinary manner. These soils fit in the orders of Vertisols, Inceptisols and Alfisols.

5.1.3 Red soil

These soils cover about 10.6 % of total geographical area in the country. Red soil contains a high percentage of iron content, which is responsible for its color. This red color can vary from red to brown, chocolate, yellow and gray. Such soils widely occur in southern part of peninsula comprising the states of Tamil Nadu, Karnataka, Maharashtra, Andhra Pradesh, Madhya Pradesh, and Goa. Texture of this soil is highly variable, which varies from loamy sand to heavy clay but generally they are loam to clay loam. These soils fit in the orders of Alfisols, Ultisols, Entisols and Inceptisols.

5.1.4 Laterite and lateritic soils

Such soils are formed due to intensive weathering of the parent rock. These are rich in aluminum and iron and are formed in wet and hot tropical areas. It occurs in about 5.5 % geographical area of the country and are abundant in the states of Tamil Nadu, Kerala, Odisha and Meghalaya. Soils are rusty red due to the presence of iron oxides. These soils are deficient in almost all the nutrients but can be managed well. Liming of such soils is essential for better crops. These soils fit in the orders of Ultisols and Alfisols.

5.1.5 Desert soil

Desert soil contains 90–95% sand and is predominantly found in low-rainfall regions. These soils are pale brown to yellowish-brown in colour and poor in nutrients and water holding capacity. It occupies about 8 % of total geographic area of the country and are found in the western part of Rajasthan, Gujarat, Haryana and Punjab. The cold desert soils are found in Leh, and Ladakh region. It has a low content of nitrogen and organic matter with very high calcium carbonate and phosphate making them infertile. These soils fit in the orders of Aridisols and Entisols.

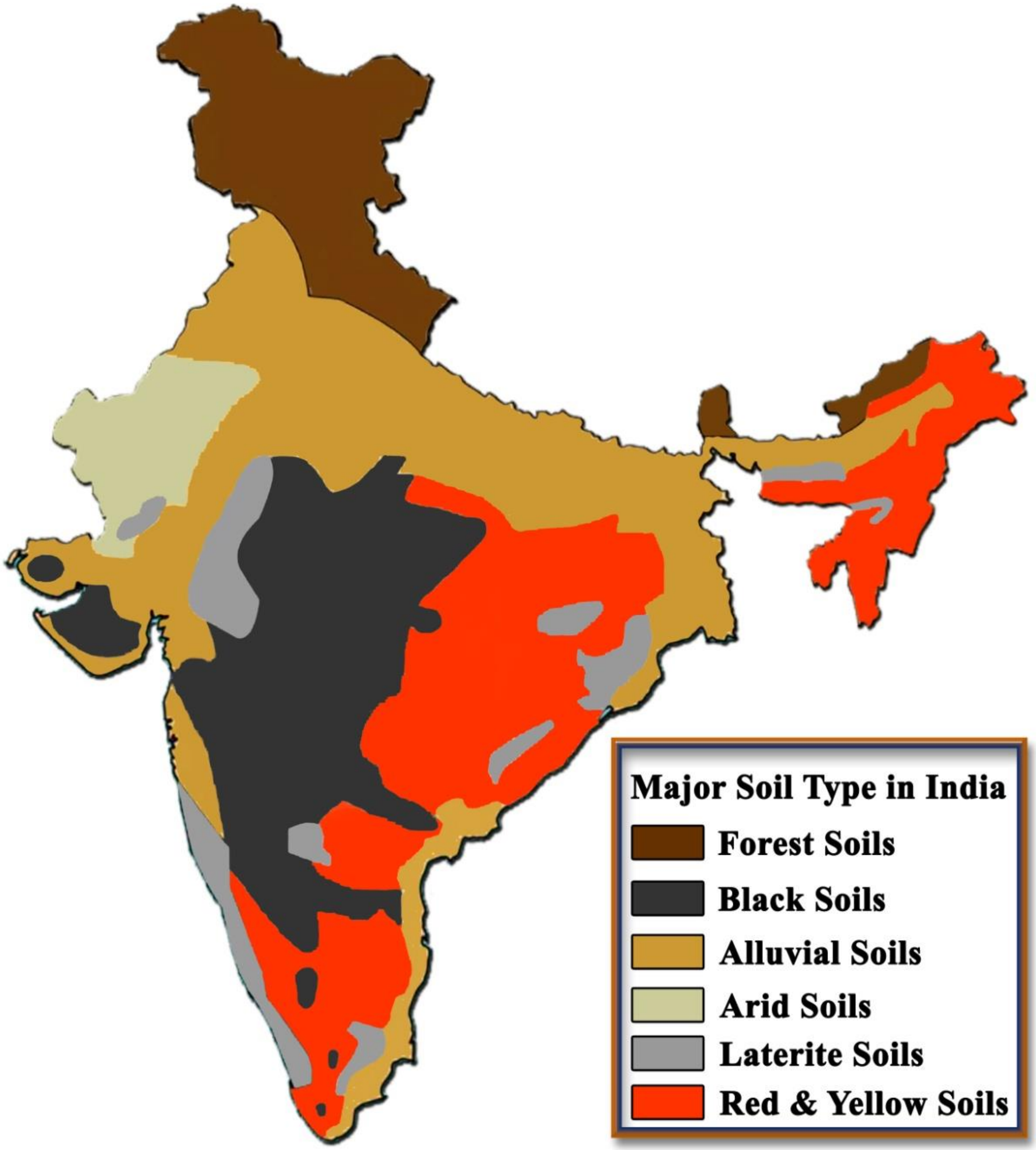
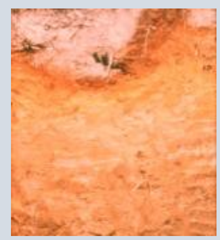
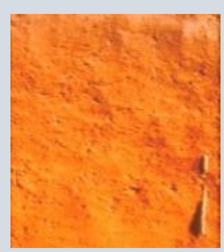
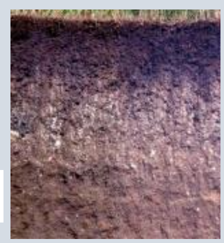
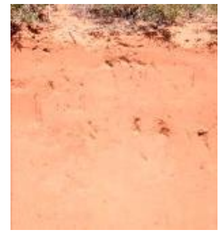


Fig. 1.28: Distribution of major soil types of India

Table 1.7: Description of Soil Orders (Fig. 1.29 A-L)

S. No.	Name of soil order	Description	Image
1	Gelisols	Gelisols are found in the Arctic and Antarctic as well as at extremely high elevations. They cover about 9% of the world's surface.	a 
2	Histosols	Histosols can be highly productive farmland when proper drainage is provided. Such soils are not suitable for foundational work or roadways. They cover about 1% of the world's surface.	b 
3	Spodosols	Spodosols are found under coniferous vegetation in humid regions of the world. They tend to be acidic, and have low fertility and low clay content. They cover about 4% of the world's surface.	c 
4	Andisols	Soils under this order are developed by the weathering of volcanic materials such as ash. They typically occur in areas with moderate to high rainfall and cool temperatures. They cover about 1% of the world's surface.	d 
5	Oxisols	Oxisols are formed in tropical and subtropical regions, such soils are dominated by the presence of iron oxides, quartz, and highly weathered clay minerals. They cover about 8% of the world's surface.	e 

6	Vertisols	Vertisols are clay-rich soils formed in arid to semi-arid region. These soils therefore shrink as they dry and swell when they become wet. They cover about 2% of the world's surface	f 
7	Aridisols	Aridisols are formed in dry climates of hot and cold desert. Aridisols often contain accumulations of salt, gypsum, or carbonates. They cover about 12% of the world's surface.	g 
8	Ultisols	Ultisols soils are formed in humid areas and are intensely weathered. These soils contain relatively high clay content in sub surface and are acidic in nature. They cover about 8% of the world's surface.	h 
9	Mollisols	Mollisols are highly fertile and are rich in calcium and magnesium. These are often found in climates with pronounced dry seasons. They cover about approximately 7% of the world's surface.	i 
10	Alfisols	Alfisols are rich in aluminium and iron oxides which are less weathered and slightly acidic soils. They cover about 10% of the world's surface.	j 
11	Inceptisols	Inceptisols occurs in wide range of parent material and climatic conditions. They cover about 17% of the world's surface.	k 

12	Entisols	Entisols occur in areas of recently deposited sediments. They are commonly occur in all environments. It occupies second largest soil order after. They cover about 16% of the world's surface.	

5.2 Problem soils in India

Certain characteristics make the soils unsuitable and uneconomical for crop cultivation in the absence of proper reclamation measures. Such soils are known as problem soils. Even a good soil may turn into a problem soil if not managed properly. Various constrain such as, excessive dryness and wetness, compaction, acidity, salinity, sodicity and lack of fertility etc. limits soil productivity making them problem soil. All soils contain soluble salts. Many of these soluble salts act as a source of essential nutrients required for plant growth. However, when the quantity and quality of salts in the soil exceeds certain limits it adversely affects crop growth and yield. Problem soils occupy about 7% of the world's surface area. The extent of salt affected soil is presented in Fig.1.30 (a, b).

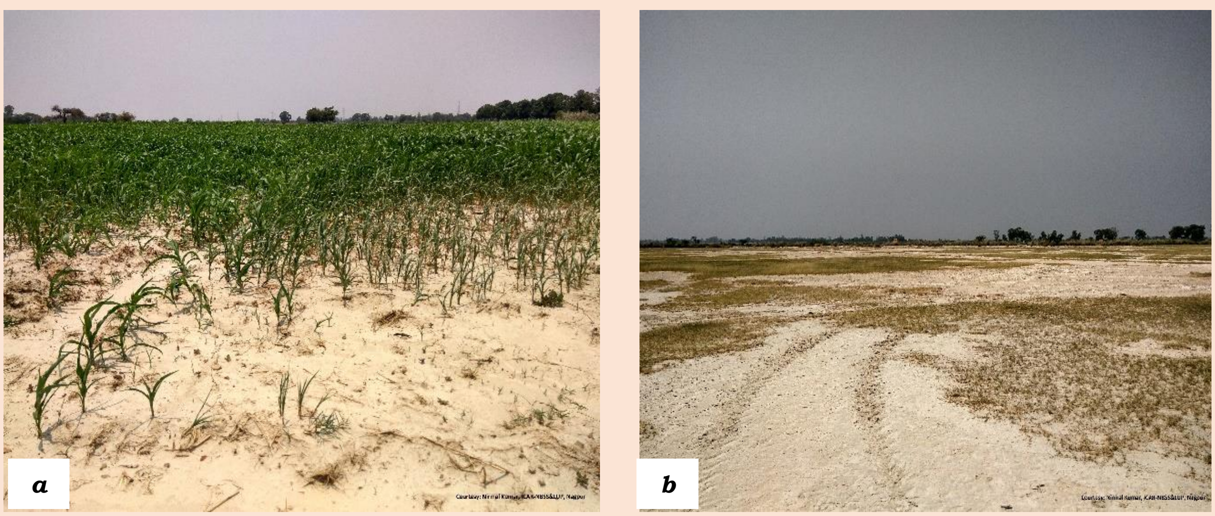


Fig. 1.30 (a, b): Salt affected soils

The salt affected soils are broadly categorised into two main groups as given below:

5.2.1 Saline soils

These soils contain higher amount of neutral soluble salts which adversely affect the plant growth. These salts are found mainly in the form of chlorides (Cl^-) and sulphates (SO_4^{2-}) of sodium (Na), calcium (Ca), magnesium (Mg) and potassium(K).

5.2.2 Sodic soils

Soils containing sodium salts capable of alkaline hydrolysis, mainly Na_2CO_3, these soils were earlier referred to as alkali soils. The distribution of salt affected soils in India is given in Fig. 1.31.

5.2.3 Acid soils

Normal soils have a pH of 6.5 to 7.5 but when the pH drops below 6.5 the soils become acidic. These soils are generally rich in aluminium and iron oxides and found in areas with high rainfall and at high altitude, when most of the basic cations (Ca, Mg) are washed away and makes the soil acidic. The distribution of acidic soils in India is given in Fig. 1.32.

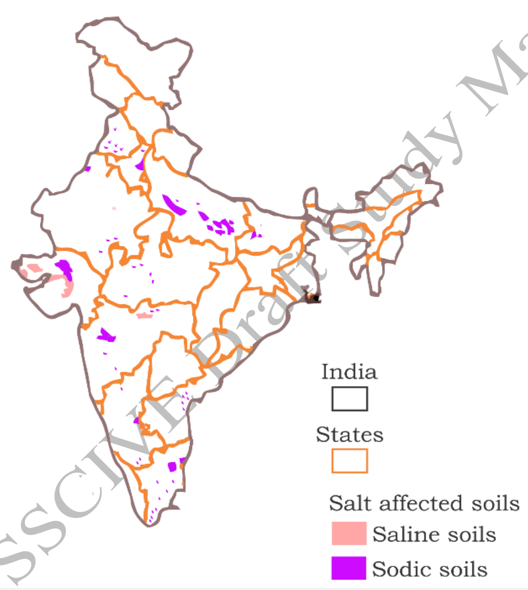


Fig. 1.31: Extent of salt affected soils in India

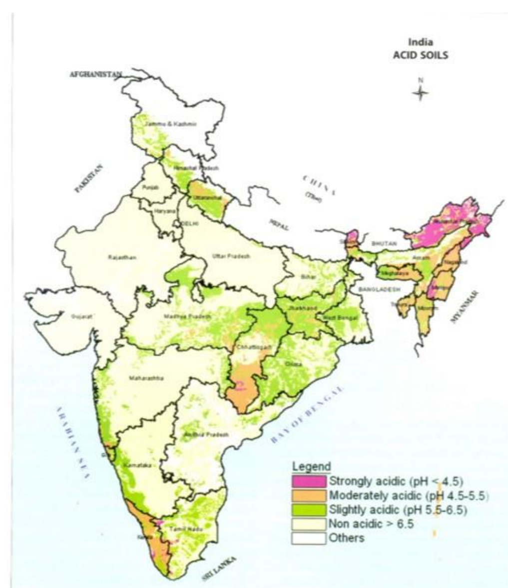


Fig. 1.32: Extent of Acid soils of India

5.3 Management of problem soils

5.3.1 Saline soils

These soils are reclaimed through scrapping, flushing and leaching processes. In scraping, we remove excess salts from the soil surface by mechanical means with the help of tools. In flushing, the excess accumulated salts are washed from the surface by flushing with good quality water whereas leaching is the most followed practice to remove excess salts by ponding fresh water on the soil surface and allowing it to infiltrate into the subsurface layers.

5.3.2 Sodic soils

Sodic soils are reclaimed by application of gypsum or calcium chloride etc. Other substances, such as sulphuric acid and sulphur compounds (Pyrite) help in the replacement of sodium in soil.

The organics such as farmyard manure, green manure and crop residues are also applied for reclaiming salt affected soils. However, this process is slow as compared to application of gypsum. Decomposition and plant root action also help dissolve the calcium compounds found in most soils, thus promoting reclamation but this is relatively a slow process.

5.3.3 Acidic soils

Application of different liming materials such as calcium carbonate (calcite), Calcium Magnesium carbonate (Dolomite) and Magnesium carbonate helps in reclaimimg acid soils. In addition, application of manures such as farm yard manures, green manures etc. helps in reclaiming them.

Check Your Progress

Multiple Choice Questions

1. Alluvial soils fit in the following soil orders
   a) Entisols
   b) Inceptisols
   c) Alfisols
   d) Aridisols
   e) All the above
2. Black soils fits in following soil orders
   a) Vertisols
   b) Inceptisols

c) Alfisols

d) All the above

3. Red soil contains a high percentage of which of the following element

a) Iron

b) Magnesium

c) Manganese

d) None of the above

4. Acid soils are

a) Rich in aluminum and iron oxides

b) Have low basic cations

c) Formed in area with high rainfall and high altitude

d) All of the above

5. To reclaim acidic soils following liming materials are used

a) Calcium carbonate (calcite)

b) Magnesium carbonate

c) Calcium Magnesium carbonate (Dolomite)

d) All of the above

Fill in the Blanks

1. ………….. soils also known as Regur or Tals soils.
2. Desert soil contains ……………. % sand.
3. Desert soils contain low amount of ………… and …………
4. …………………. soils are formed by intensive weathering process which are rich in aluminum and iron.
5. Soils belonging to ……………… order is not suitable for foundations or roadways.

True or False

1. Soils don't have scientific classification similar to animals and plants species.
2. Saline soils largely consist of chlorides (Cl^-) and sulphates (SO_4^{2-}) sodium (Na), calcium (Ca), magnesium (Mg) and potassium.
3. Sodic soils are reclaimed by application of lime or calcium carbonate.
4. Alluvial soils cover largest area in India.\

5. Soils have been classified into 12 dominant soil orders worldwide.
6. Saline soils are reclaimed through scrapping, flushing and leaching processes.

Module 2
Plant Nutrients and their Management

Module Overview

Like other living things, plants also need different nutrients for their growth, development, and life cycle completion. Out of a total 118 element known to us, as many as 90 elements are found in the plant system. However, only 17 elements are identified as essential elements.

Learning Outcomes

After completing this module, you will be able to:

- Identify and describe the essential plant nutrients, including macro and micronutrients, their functions, and deficiency symptoms in plants.
- Explain the types, benefits, and application methods of manures and fertilizers, and their roles in enhancing soil fertility and plant growth.
- Discuss strategies for nutrient management in soil, including soil testing, balanced fertilization, organic amendments, and integrated nutrient management practices to optimize crop productivity and sustainability.

Module Structure

- Session 1: Essential Plant Nutrients
- Session 2: Manures and Fertilizers
- Session 3: Nutrient Management in Soil

Session 1: Essential Plant Nutrients

1.1 Criteria of essentiality

Arnon and Stout (1939) proposed three criteria to qualify any element as "essential nutrient" for the plant system. The term "functional nutrients" is used for any mineral element that have functions in plant metabolism, irrespective of their specific role. The criteria for essentiality are given in the Fig. 2.1.

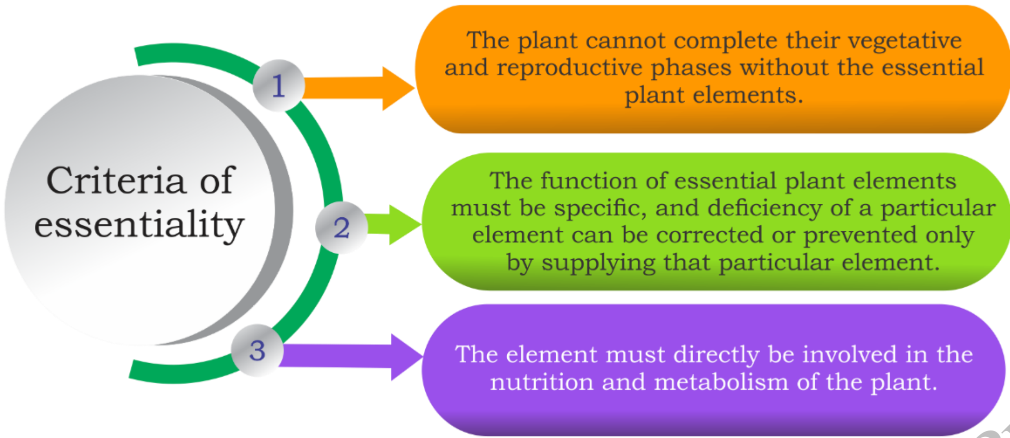


Fig. 2.1: Criteria of essentiality of plant nutrients

1.2 Essential elements

There are 17 essential elements which have been identified. (Fig. 2.2) In addition sodium, cobalt, vanadium, and silicon are considered as functional nutrients.

Essential elements

Human Beings (19)	Farm Animals (18)	Plants (17)
Carbon (C)	Carbon (C)	Carbon (C)
Hydrogen (H)	Hydrogen (H)	Hydrogen (H)
Oxygen (O)	Oxygen (O)	Oxygen (O)
Nitrogen (N)	Nitrogen (N)	Nitrogen (N)
Phosphorous (P)	Phosphorous (P)	Phosphorous (P)
Potassium (K)	Potassium (K)	Potassium (K)
Calcium (Ca)	Calcium (Ca)	Calcium (Ca)
Magnesium (Mg)	Magnesium (Mg)	Magnesium (Mg)
Sulphur (S)	Sulphur (S)	Sulphur (S)
Iron (Fe)	Iron (Fe)	Iron (Fe)
Manganese (Mn)	Manganese (Mn)	Manganese (Mn)
Zinc (Zn)	Zinc (Zn)	Zinc (Zn)
Copper (Cu)	Copper (Cu)	Copper (Cu)
Molybdenum (Mo)	Molybdenum (Mo)	Molybdenum (Mo)
Chlorine (Cl)	Chlorine (Cl)	Chlorine (Cl)
Sodium (Na)	Sodium (Na)	Nickel (Ni)
Iodine (I)	Iodine (I)	Boron (B)
Cobalt (Co)	Cobalt (Co)	
Fluorine (F)		

Fig. 2.2: Essential elements for Human Beings, Farm Animals and Plants

- Plants absorb C, H, and O mostly in the forms of CO_2 and H_2O from air and water. These three elements form the basis for carbohydrates such as sugars and starch which provide strength to the cell walls, stems, and leaves therefore these elements are called as structural elements.
- The elements C, H and O act as source of energy for the plants and other organisms.

- The other 14 essential elements namely N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, Cl, Ni and B are absorbed by the plants from soil.

1.2.1 Macronutrients

The N, P, K, Ca, Mg and S are required in relatively larger amounts hence these are termed as *macronutrients*. The macronutrients are further classified into primary and secondary nutrients.

The primary nutrients include N, P, and K. These nutrients contribute to plant nutrient needs, function of plant enzymes and biochemical processes, and integrity of plant cells. The deficiency of these nutrients leads reduced plant growth and yield. Thus, N, P and K are the three most important nutrients supplied through fertilizers.

1.2.2 Secondary nutrients and micronutrients

Secondary nutrients include Ca, Mg, and S. The other essential elements namely Fe, Mn, Zn, Cu, Mo, Cl, Ni, B are known as micronutrients or trace elements or minor elements. As these nutrients are taken by the plants in relatively smaller amounts (≤100 mg/kg/dry weight). The overall classification of essential elements is shown in Figure 2.3.

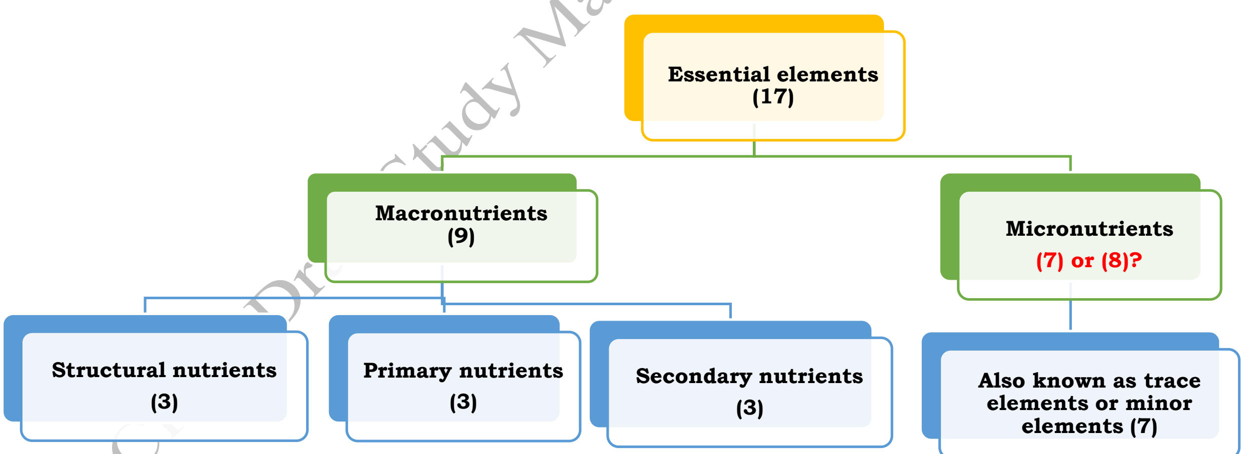


Fig. 2.3: Classification of essential elements

1.3 Nutrient uptake by plants

The nutrient uptake is done by all young roots especially in the zone of maturation (Figure 2.4 a, b). Root hairs increase the root's absorptive surface area. The process by which nutrients are taken up by the plant roots is known as nutrient uptake. Plant roots are essential for water and nutrient uptake. A typical root system depicting different zones is shown in Figure 2.4a.

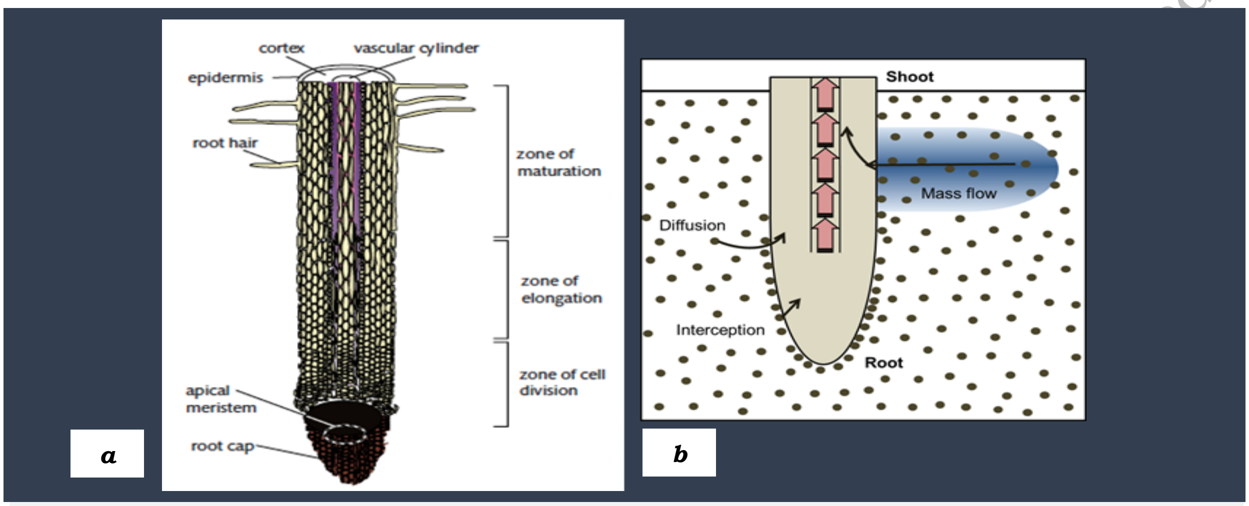


Fig. 2.4 (a, b): Mechanism of uptake of nutrients by roots

a: Schematic view of Plant root system; b: Element movement to root surface

Plants receive most of the carbon and oxygen as CO_2 from air and hydrogen from H_2O.The three nutrients (C, H and O) enter the plant in molecular form whereas the rest of essential nutrients are taken up from the soil by the plants through the following methods:

1.3.1 Mass flow

It is the movement of dissolved nutrients (in water) into a plant as the plant absorbs water from roots and loses it by the process of transpiration (i.e., loss of water in the form of water vapor from the aerial parts of plants). This process is responsible for transport of most of the nitrate, sulfate, calcium, and magnesium in soil to the plants.

1.3.2 Diffusion

Nutrients found in higher concentrations in a solution (soils) move to their lower concentrations (plants) to reach equilibrium by a process known as diffusion. Thus, a high nutrient concentration in the soil solution and a low nutrient concentration at the root zone will trigger the nutrient movement towards the root. It is important for the transport of phosphorus and potassium.

1.3.3 Root interception

It is a minor pathway for nutrient transfer which occurs when the growth of a root is in contact with soil colloids that contain nutrients. The root then absorbs the nutrients. It is an important method of transport and uptake for calcium (Ca) and magnesium (Mg). The processes involved in the uptake of different nutrients is summarized in Table 2.1.

Table 2.1: Processes Involved in the uptake of Different Nutrients by Plants

Nutrient	Mass Flow	Diffusion	Root Interception
Nitrogen	✓		
Phosphorus		✓	
Potassium	✓	✓	
Calcium	✓		✓
Magnesium	✓		✓
Sulfur	✓	✓	
Boron	✓		
Copper	✓		
Iron	✓	✓	✓
Manganese	✓		✓
Zinc	✓	✓	✓
Molybdenum	✓		

1.4 Form of nutrient uptake and its mobility

An ideal soil contains 50% solid and 50% pore space. These pore spaces hold the water and the dissolved nutrient ions. The roots, especially the root hairs, draw the nutrient directly from the soil solution through the exchange processes. If a cation is removed from the solution, the root gives up a H^+ to replace it in the soil solution. If an anion is absorbed from the solution, the root gives up an anion to replace it. This exchange process maintains the electrical balances in the soil and plant system.

After crossing the root wall, the nutrients enter into the plant vascular system to reach the entire plant system where they are utilized. All the three nutrient uptake processes i.e., mass flow, diffusion, and root interception operate simultaneously. However, the importance of these processes entirely depends on plant species, nutrient type, and soil conditions (i.e., texture and moisture content). A plant's ability to obtain a nutrient depends not only on the availability of a particular nutrient but also on its mobility in the soil (Table 2.2). Those nutrients that move by diffusion (e.g., phosphorous) tend to be much less mobile than those that can move by mass flow (e.g., nitrogen).

Table 2.2: Available Forms of Plant Nutrients and their Mobility in Soil

Nutrients	Plant-available form(s)	Mobility in soil	Mobility in plant
Structural elements			
Carbon, C	Molecular	-	-
Hydrogen, H	Molecular	-	-
Oxygen, O	Molecular	-	-
Primary nutrients			
Nitrogen, N	NO_3^-, NH_4^+	Mobile (NO_3^-) Immobile (NH_4^+)	Mobile
Phosphorus, P	HPO_4^{2-}, $H_2PO_4^-$	Immobile	Somewhat mobile
Potassium, K	K^+	Somewhat mobile	Very Mobile

Secondary nutrients			
Calcium, Ca	Ca^{2+}	Somewhat mobile	Immobile
Magnesium, Mg	Mg^{2+}	Immobile	Somewhat mobile
Sulphur, S	SO_4^{2-}	Mobile	Mobile
Micronutrients			
Boron, B	$B(OH)_3$, $B(OH)_4^-$	Very mobile	Immobile
Chlorine, Cl	Cl^-	Mobile	Mobile
Cobalt, Co	CO^{2+}	Immobile	Somewhat mobile
Copper, Cu	Cu^{2+}	Immobile	Immobile
Iron, Fe	Fe^{2+}, Fe^{3+}	Immobile	Immobile
Manganese, Mn	Mn^{2+}	Mobile	Immobile
Molybdenum, MO	MoO_4^-	Somewhat mobile	Immobile
Zinc, Zn	Zn^{2+}	Immobile	Immobile

1.4.1 Factors affecting nutrient uptake

Agriculture production largely depends on soil productivity and nutrient uptake. Soil productivity and nutrient uptake are interrelated with numerous factors as shown in Fig. 2.5.

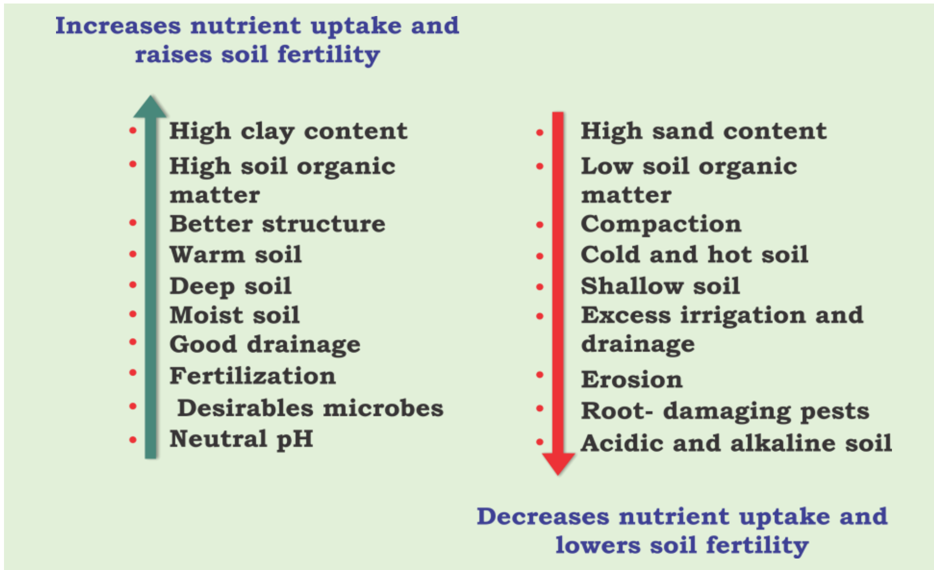


Fig. 2.5: Factors affecting nutrient uptake.

1.4.2 Effect of soil pH on nutrient availability

The salient points on the effects of soil pH on nutrient availability are given below:

- Most crops do well in the pH range of 6.5 to 7.5.
- The N, P, K, Ca, Mg, and S are readily available between pH range from 6.5 to 7.5.
- The availability of the most micronutrient (Zn, Fe, Mn and Cu) is maximum in the soil with low pH (i.e., pH<6.5).
- Molybdenum (Mo) availability increases with an increase in soil pH.
- The acidic conditions in soil occur due to high rainfall and leaching of alkalis such as Ca, Mg, etc. This condition leads to toxicities of the Al, Fe, and other micronutrients. The relationship between soil pH and the availability of plant nutrients is shown in Fig. 2.6.

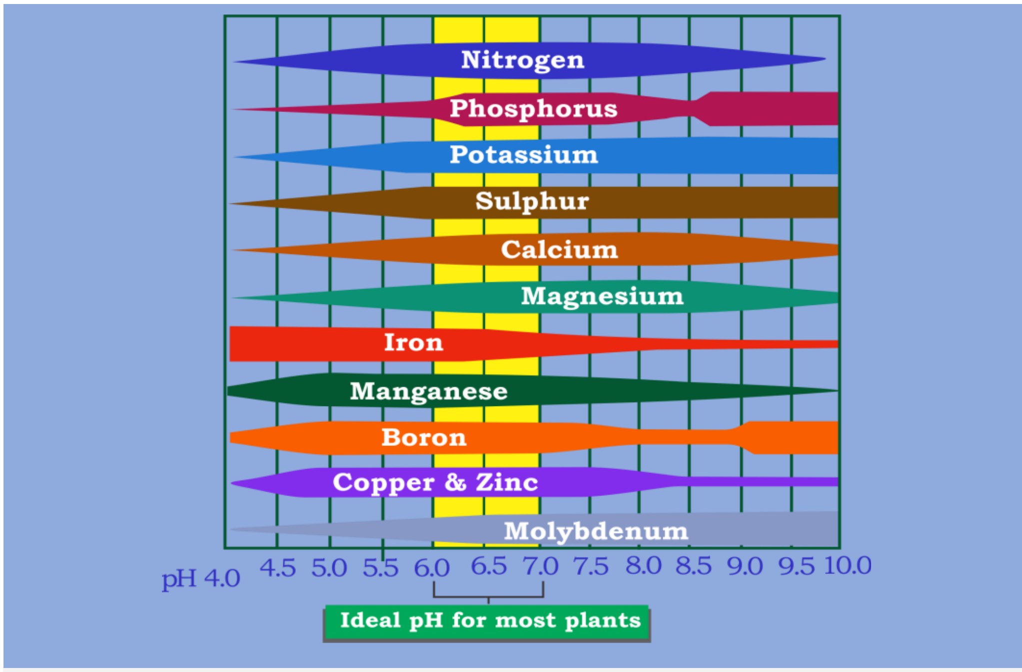


Fig. 2.6: Rrelationship between soil pH and the nutrient availability of nutrients

The information about the pH status of a farmer's field is extremely useful to him for planning the different types of crops for a particular season. A list of crops suitable for growing in different pH range is shown in Table 2.3.

Table 2.3: Crop Suitability at Different ph

pH Range				
4.0-6.0	**5.0-6.5**	**6.0-7.5**	**5.0-7.5**	**6.0-8.0**
Potato	Apple, Blackberry, Cranberry, Gooseberry, Mango, Melon, Pineapple, Pomegranate, Watermelon, Basil, Fennel, Peanut, Sweet potato, Rice, Soybean.	Apricot, Cherry, Grapevine, Grapefruit, Hazelnut, Hop, Lemon, Lychee, Mulberry, Nectarine, Peach, Plum, Bean, Beetroot, Broccoli, Cabbage, Celery, Chinese cabbage, Lettuce, Millet, Mustard, Onion, Pea, Peppermint, Radish, Spinach.	Banana, Strawberry, Raspberry, Carrot, Cauliflower, Sweet corn, Cucumber Garlic, Lentil, Parsley Pepper, Pumpkin Spearmint, Thyme, Tomato Turnip.	Avocado, Asparagus, Ginger, Mint.

Check Your Progress

Multiple Choice Questions

1. The criteria of essentiality for the plant system was proposed by
   a) Hans Jenny
   b) Arnon and Stout
   c) Robert hook
   d) J. C. Bose
2. Which is not the process of plant nutrient uptake
   a) Mass flow
   b) Diffusion
   c) Root inception
   d) Photosynthesis
3. Which one of the following affects the nutrient uptake processes
   a) Soil pH
   b) Nutrient Availability
   c) Root distribution
   d) All the above
4. Which one of the following is not a micronutrient
   a) Calcium
   b) Iron
   c) Zinc
   d) Copper
5. Nutrient uptake is mostly done by
   a) Root hair
   b) Cortex
   c) Epidermis
   d) Leaf

Fill in the Blanks

1. The plant system needs ……. essential elements to complete their life cycle.
2. The quantity of micronutrient requirement in plant system is less than ………… mg/kg of plant weight.
3. Phosphorous uptake in plant system is governed by the process of …………….
4. The acidic conditions in a soil prevail under ………. rainfall conditions.
5. Nitrogen uptake in plant system is mostly through the process of……..

True or False

1. Molybdenum (Mo) availability increases with the increase in soil pH.
2. The availability of the micronutrient increases with increasing pH.
3. Uptake of iron in the plant system is only through mass flow.
4. Most crops do well in the pH range of 6.5 to 7.5.
5. The availability of Nitrogen will be increase with the increase in soil pH.

Session 2: Manures and Fertilizers

Soil provides all the essential nutrients to the plants for their growth and food production. Due to continuous removal of these nutrients through crops, soil becomes deficient in essential nutrients. Therefore, we need to provide additional nutrients to soil by application of manures and fertilizers to improve the soil fertility and crop production. Fertilizers are organic or inorganic chemical synthetic compounds that supply nutrients to crops to increase the crop yield. For example, urea is the organic synthetic fertilizer, whereas, ammonium sulphate is an example of inorganic synthetic fertilizer.

2.1 Fertilizers and their types

Fertilizers which provide primary nutrients such as nitrogen, phosphorous and potassium (N, P and K) to plants are known as primary nutrient fertilizer. The secondary nutrient fertilizers provide the secondary nutrient such as calcium, magnesium, and Sulphur to the plants.

Some fertilizer products supply only one primary nutrient. For example, Urea supplies only nitrogen. Similarly, super phosphate supplies only phosphorous to plants. These types of fertilizers are called straight fertilizers.

The fertilizers which supply more than one primary nutrient are called complex fertilizers. For example, ammonium phosphate supplies nitrogen as well as phosphorus to the plant.

The fertilizer which primarily supplies nitrogen is known as nitrogenous fertilizer. Similarly, phosphorus supplying fertilizers are known as phosphatic fertilizers and potassium supplying fertilizers are known as potassic fertilizers. Similarly, Sulphur and other micronutrient fertilizers provide Sulphur and different micronutrients to the plant. However, the use of Sulphur and micronutrient fertilizer in crop production is comparatively less.

2.1.1 Nutrient content of different fertilizers and manures

The quantity of nutrients provided by different organic and inorganic fertilizers is different depending on their constituents. A list of some of the commonly used fertilizers along with their chemical formula and percentage composition of their nutrient constituents is presented in table 4.

Table 2.4: Commonly Used Fertilizers with their Nutrient Contents

Common name	Chemical formula	N (%)	P_2O_5 (%)	K_2O (%)
Ammonium nitrate	NH_4NO_3	34	0	0
Ammonium sulphate	$(NH_4)_2SO_4$	21	0	0
Ammonium nitrate-urea	NH_4NO_3 + $(NH_2)_2CO$	32	0	0
Anhydrous ammonia	NH_3	82	0	0
Aqua ammonia	NH_4OH	20	0	0
Urea	$(NH_2)_2CO$	46	0	0
Superphosphate (Single, double and triple)	$Ca(H_2PO_4)_2$	0	20-46	0
Monoammonium phosphate	$NH_4H_2PO_4$	13	52	0
Diammonium phosphate	$(NH_4)_2HPO_4$	18	46	0

Urea-ammonium phosphate	$(NH_2)_2CO$ + $(NH_4)_2HPO_4$	28	28	0
Potassium chloride	KCl	0	0	60
Monopotassium phosphate	KH_2PO_4	0	50	40
Potassium nitrate	KNO_3	13	0	45
Potassium sulphate	K_2SO_4	0	0	50

2.2 Manures

Manures are the decomposed plant and animal matter. Manures provide most of the plant nutrients but in small quantities. Use of manures has additional benefits over synthetic fertilizers in that they increase the soil organic matter (SOM) and improve the structure and stability of soil. Additionally, manures provide food for soil microorganisms. Manures increase the microbial activity and help in converting unavailable forms of plant nutrients into available forms. Some of the commonly used manures are farmyard manure (FYM), vermicompost, poultry manures and green manures (Figure 2.7 a, b, c, d). The nutrient content in different types of manures is shown in table 5.

Table 2.5: Nutrient Content in Different Manures

Type of Manure	N %	P %	K %
Farmyard Manure	0.5	0.2	0.5
Vermicompost	1.8	3.8	1.3
Poultry Manure	0.5 – 0.9	0.4-0.9	1.2-1.7
Green Manure	3.5	0.6	1.2

a. **Farmyard manure (FYM):** The FYM is a decomposed mixture of dung and urine of farm animals and litter used as bedding material and residues from the fodder fed to the cattle. The farm yard manure has been traditionally used as manure since long back. It is the most common form of organic manure applied in agricultural fields. The regular use of FYM increases soil physical health by improving aggregate stability and decreasing soil bulk density.

b. **Green Manures:** Green manuring is the practice of mixing undecomposed green plant into the soil. It improves the soil structure, soil organic carbon (SOC) and soil fertility. Green manuring also prevents the soils from erosion. Some of the green manure crops are cow pea (*Vigna unguiculata*), Dhaincha (*Sesbania aculeate*), Sunn hemp (*Crotalaria juncea*) and). Green leaf manures are Glyricidia (*Glyricidia maculeata) Pongania (Pongania pinnata), Gulmohar (Delonix regia), Golden shower (Casia fistula), Jal kumbhi or Water hyacinth (Eichhornia crassipes) and Neem (Azadirechta indica)*

c. **Vermicomposting:** Certain species of earthworm transform the organic wastes into the nutrient rich manures which is called vermicompost. *Eisenia foetida* species is most efficient in vermicomposting. The partly degraded cow dung, sheep dung, cane trashes, city solid wastes, poultry farm wastes and other domestic wastes are used as substrate by earthworms who transform these waste substrates into vermicompost in 60 to 90 days.

d. **Poultry manure:** It is the waste product from poultry production. It includes waste poultry feed, solid and liquid poultry dropping, litter, eggshell, feathers and the wastes from poultry sheds. The decomposition of these wastes is essential with bacteria or fungi before using it as manures in the agricultural fields. It is a good source of nitrogen (N), phosphorus (P) and trace elements. It also improves physical, chemical and biological health of soil.

a. Farmyard Manure

b. Vermicompost

c. Poultry Manure

d. Green Manure (Dhaincha)

Fig. 2.7: Different types of manures

Check Your Progress

Multiple Choice Questions

1. Which one of the following is not used as green manuring crop?
   a) Cow pea
   b) Dhaincha
   c) Wheat
   d) Sunhemp
2. A fertilizer can be:
   a) Organic synthetic compound
   b) Inorganic synthetic compound
   c) Both
   d) None
3. The nitrogen content in urea is
   a) 20%
   b) 46%
   c) 18%
   d) 28%

4. The diammonium phosphate contains
   a) 18% N
   b) 46% P_2O_5
   c) Both
   d) None
5. Which one of the following has higher nitrogen content?
   a) Farmyard manure
   b) Vermicompost
   c) Poultry Manure
   d) Green Manure

Fill in the Blanks

1. The concentration of nitrogen in farmyard manure is …………
2. Fertilizer which provides only primary nutrient called as……………
3. Fertilizer which supplies only one primary nutrient is called………..
4. Diammonium phosphate is the example of ……………fertilizer
5. In potassium chloride, the amount of K_2O is ……….

True or False

1. Urea can be directly absorbed by the plant system for their growth.
2. The farmyard manure decreases the soil health in a long run
3. Potassium chloride is the example of straight fertilizer.
4. Any cereal crops such as rice, wheat, maize etc. can be used as green manure crops.
5. The green manuring crops also prevent soil erosion.

Session 3: Nutrient Management in Soil

As you know by now that nutrients are important for plant growth therefore, their appropriate management in soil plays an important role in maintaining soil health and crop productivity. In this session we are going to study about soil fertility and soil productivity.

3.1 Soil fertility and productivity

As a student of the field of soils you should be able to understand the subtle difference between the '*ability of soil to supply essential plant nutrients' and the 'ability of crop production of that soil'.* It is not always true that a soil having a good supply of the essential nutrients will always have the ability to produce excellent crops. All the productive soils are fertile but not all fertile soils are productive. A productive soil is one that has optimal total environmental conditions for plant growth. Soil productivity is a broad term and fertility is only one of the factors that determine the crop yields.

a. Soil fertility

It is the ability of a soil to supply essential plant nutrient in adequate amount for plant growth and agricultural production. Managing soil fertility by managing nutrients to improve crop production is the prime focus of soil science.

b. Soil productivity

Soil productivity means the *crop producing capacity of a soil* which is measured in terms of tons of yield in a given environment. It is basically measured in terms of economic output such as grain yield and biomass yield.

Productive soil must contain all the 17 essential nutrients required by the plants. Soil productivity is a result of how well the soil is able to receive and store moisture and nutrients as well as providing a desirable environment for all plant root functions. The total quantity of nutrients is not only being sufficient but they should also be present in an easily "available" form and in "balanced" proportions.

Over and above fertility, other factors which decide soil productivity are agricultural management practices such as tillage, fertilization, crop rotation, irrigation and drainage.

3.2 Total nutrients

It is the total amount of nutrients present in a soil. The presence of total quantities of essential nutrients in a soil does not guarantee the availability of these nutrients in full amount for the growing plants, because other factors such as soil moisture content, soil temperature, pH, soil physical conditions, presence of toxic elements and salts may be limiting the nutrients available to the plants.

3.3 Available nutrients

Any nutrient in the soil solution that can be absorbed readily by plant roots is termed as available nutrient.

Available amounts of nutrients are mostly much lower than the total nutrient present in the soil. In other words, only a small fraction of total nutrients are available to plants.

Nutrient requirements of major crops:

Practical recommendations and guidelines on nutrient management for different crops are given in Table 1.6 below.

Table 1.6. Recommended Fertilizer Doses in Major Crops.

Name	Scientific Name	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Rice	*Oryza sativa*	60	30	30
Wheat	*Triticum aestivum*	120	60	40
Maize	*Zea mays*	120	60	40
Sorghum	*Sorghum bicolor*	100-120	50	40
Pearl millet	*Pennisetum typhoides*	100-120	40-60	30-40
Barley	*Hordeum vulgare*	80	50	50
Chickpea	*Cicer arietinum*	20	60	20
Lentil	*Lens esculenta*	20-25	50-60	-
Field pea	*Pisum spp.*	20-30	60-70	30-40
Pigeon pea	*Cajanus cajan*	20-30	80-100	40-60
Green gram	*Vigna radiata*	15-20	40-50	-
Black gram	*Vigna mungo*	15-20	50-60	30-40
Cowpea	*Vigna sinensis*	15-20	50-60	-

Soybean	*Glycine max*	20-30	70-80	50-60
Groundnut	*Arachis hypogaea*	20-40	50-60	30-40
Sesame	*Sesamum indicum*	30	60	30
Castor	*Ricinus communis*	60	40	40
Rape seed and Mustard	*Brassica spp.*	60-90	60	40
Sunflower	*Helianthus annuus*	60-80	60	40
Sugarcane	*Saccharum officinarum*	120-150	80	60
Potato	*Solanum tuberosum*	170-180	25	250
Tobacco	*Nicotiana spp.*	20-30	50	30-50

Note: The recommended fertilizer dose for all crops may vary with the region; Please refer ICAR Institutes/ State Agriculture Universities for specific information

3.3.1 Integrated nutrient management system (INMS)

Integrated nutrient management system (INMS) refers to ensuring plant nutrient supplies at an optimum level for sustaining crop productivity. This can be achieved by application of nutrients from different sources in an integrated manner. The sources include balanced quantities of organic and inorganic fertilizers in combination with specific microorganisms to make more nutrients available to plants without polluting the environment. INMS acts as a driving force to convert low fertile lands into productive ones.

a. Components of INMS

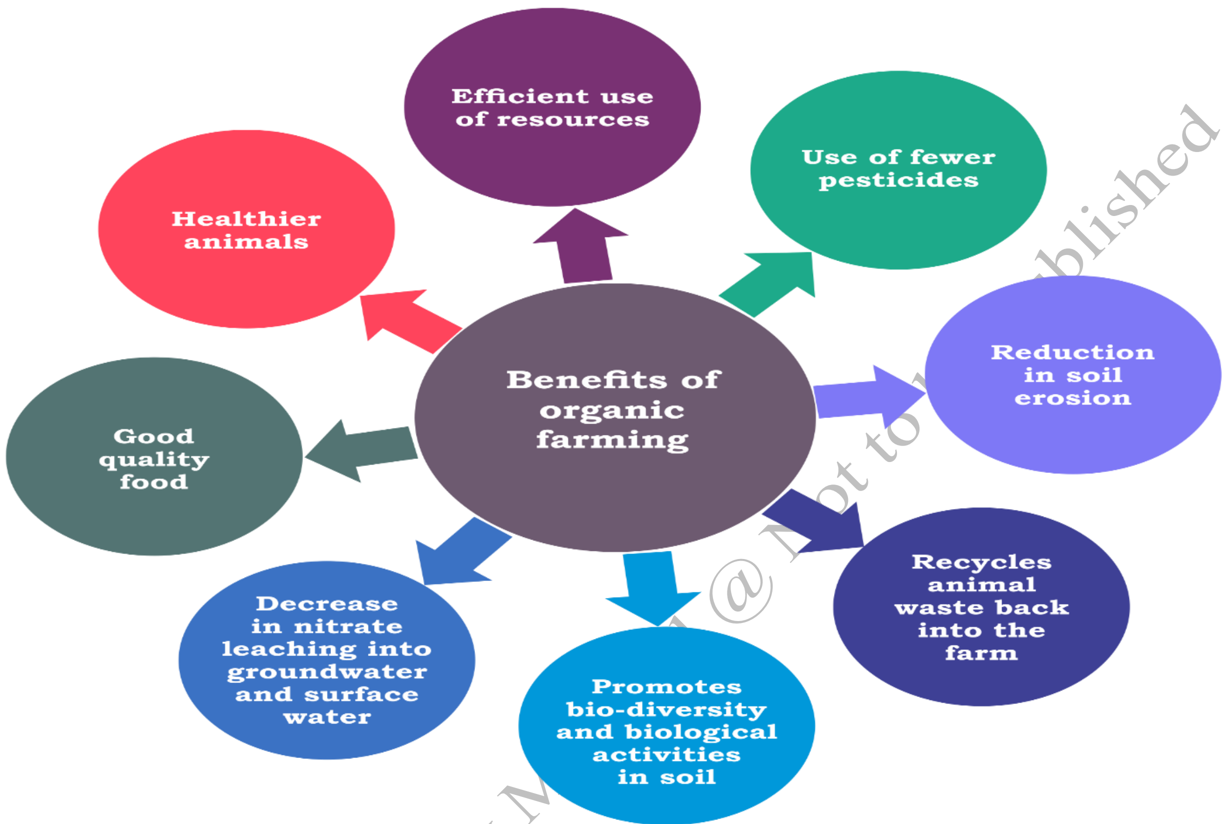
- Inorganic fertilizers (urea, single super phosphate etc.)
- Organic manures (farmyard manure, compost, green manures and vermicompost)
- Crop residues/wastes
- Legumes and bio-fertilizers

b. Advantages of INMS: The different advantages of INMS are briefly described in the Fig. 2.8.

Fig. 2.8: Advantages of INMS

3.4 Organic farming

Organic farming is a practice for plant nutrient management from organic sources only. It involves the use of materials from biological sources, avoiding synthetic materials like fertilizers, hormones, pesticides and feed additives etc. Organic farming maintains soil fertility and animal health as well as protection of environment thereby minimizing pollution. Organic farming is based on the principles of crop rotation, green manuring, farm waste recycling, biological pest control, mineral and rock additives like rock phosphates, animal manures and use of nutrient mobilizing microorganisms. It uses pesticides and fertilizers if they are of organic nature. Organic fertilizers are fertilizers of animal and plant origin, such as compost, farmyard manure, crop residues and human excreta etc. However, due to less use of chemicals and fertilizers, the yields in organic farming are lower as compared to conventional farming. Nonetheless, the benefits associated with organic farming have made it popular now-a-days.



Check Your Progress

Multiple Choice Questions

1. The crop producing capacity of a soil is known as
   a) Soil productivity
   b) Soil fertility
   c) Both
   d) None
2. In soybean, recommended dose of nitrogen is the
   a) 20-30 kg/ha
   b) 40-60 kg/ha
   c) 100 kg/ha
   d) All

3. The recommended dose of Nitrogen in wheat crop is
   a) 100 kg/ha
   b) 120 kg/ha
   c) 500 kg/ha
   d) All
4. The soil organic matter improves
   a) Soil structure
   b) Soil moisture retention
   c) Nutrient supply capacity
   d) All of the above
5. The scientific name of potato is
   a) Solanum tuberosum
   b) Vigna radiate
   c) Vigna mungo
   d) Triticum aestivum

Fill in the Blanks

1. The ability of a soil to supply essential plant nutrient called ....
2. A .... fraction of total nutrients are available to plants.
3. Organic fertilizers are fertilizers of ....and .... origin.
4. Plant nutrients are important for .... and other functions.
5. The scientific name of maize is ....

True or False

1. All the productive soils are fertile but not all fertile soils are productive.
2. The agricultural management practices such as tillage, fertilization, crop rotation, irrigation, and drainage can affect the soil productivity.
3. The total nutrient in soil is always higher than the plant available nutrients.
4. In integrated nutrient management system, green manuring is not used.
5. Nutrient present in the soil solution that can be absorbed readily by plant roots is called total nutrients.

Module 3
Soil and Water Testing

Module Overview

We often test our blood samples to know our health conditions, similarly, soil and water analysis are important for knowing soil health. Soil testing is essential for knowing fertility status and soil health. Soil health refers to the capacity of the soil to perform the different functions e.g., nutrient cycling, buffering, filtering, biodiversity and crop production etc.

Similarly, testing of water is equally important which is helpful in knowing the quality of water and its use for irrigation. Results from the testing of soil and water are the basis for nutrient application through fertilizers and manures to meet the specific needs of different crops. The water analysis data is essential to judge the suitability of water for crop irrigation and drinking purpose. The core subject for the job role i.e., 'soil and water test' is discussed in this Module

Learning Outcomes

After completing this module, you will be able to:

- Explain the importance of soil and water testing in agriculture, including its role in diagnosing soil fertility, water quality, and making informed management decisions to improve crop productivity and environmental sustainability.
- Identify and describe the instruments used in soil and water testing, such as pH meters, spectrophotometers, EC meters, and titrators, and understand their operating principles and maintenance requirements.
- Describe important soil and water testing parameters, including pH, electrical conductivity (EC), nutrient levels, organic matter content, and contaminant concentrations, and interpret their significance for soil and water management.

Module Structure

- Session 1: Soil and Water Testing and its Importance
- Session 2: Instruments Used in Soil and Water Testing
- Session 3: Describe Important Soil and Water Testing Parameters

Session 1: Soil and Water Testing and its Importance

If you have to apply fertilizers and manures to a crop, how will you decide which fertilizers to apply and in what quantities? You can decide easily if you have an exact idea of the amount of available nutrients already present in the soil and if the soil needs any additional nutrients in the form of fertilizers or not. The basic purpose behind soil testing is to recommend optimum quantities of fertilizers for plant growth and crop production. Soil testing serves a variety of purposes as shown in figure 3.1.

- **To study the fertility status of the field.**
- **To study the nutrient deficiency symptoms in different crops.**
- **To know if the soil is problematic or not (acidity, salinity, alkalinity etc.).**
- **To prepare soil health card and prescribe fertilisers and manures.**
- **To help in proper planning of soil and water conservation measures.**

Fig. 3.1: Purposes of soil testing

Soil testing is now an intrinsic part of modern farming techniques. Parameters of soil testing range from soil pH to available nutrients. Similarly, water analysis is done by adopting standard procedures. Before a soil or water sample is tested, it is essential to collect the samples following standard protocols. In this section, we will discuss different stages of sample collection and analysis.

Do you know!

The soil analysis information is also required for surveys and mapping, constructions, building works and land use planning etc. However, the procedures and techniques of soil testing for civil engineering purposes are a different paradigm altogether.

1.1 Process of soil and water testing

The process of soil and water testing is divided into four major stages which are described in the figure 3.2.

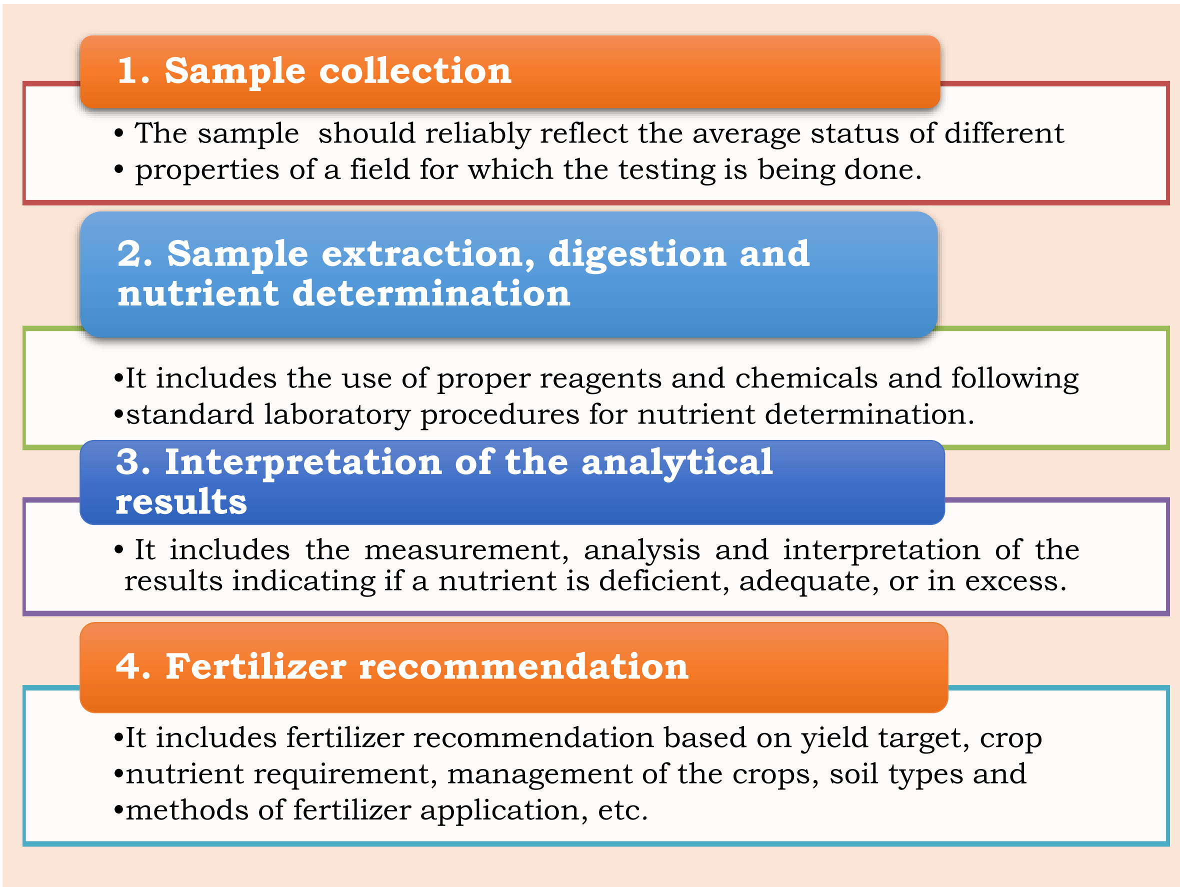


Fig. 3.2: Process of soil and water testing

1.1.1 Soil sampling

Before we begin the process of soil sampling, it is ensured that the collected soil samples must be the true representative of the sampled field or location. To achieve this, following steps are taken:

i. Observe the field and visually divide the field into different homogenous unit based on farmer's observation and experience.

ii. From each sampling point remove litter and crop residue from the soil surface with help of spade or *khurpi.*

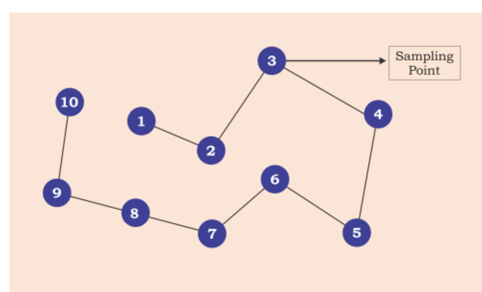


Fig.3.3: Sampling points (1-10)

iii. Select 5-10 equidistant sampling point (1-10 as shown in figure 3.3) in the field in a zig-zag manner.

iv. Make a V-shaped cut (Figure 3.4) at the sampling point to a depth of 15 cm using spade or *khurpi*.

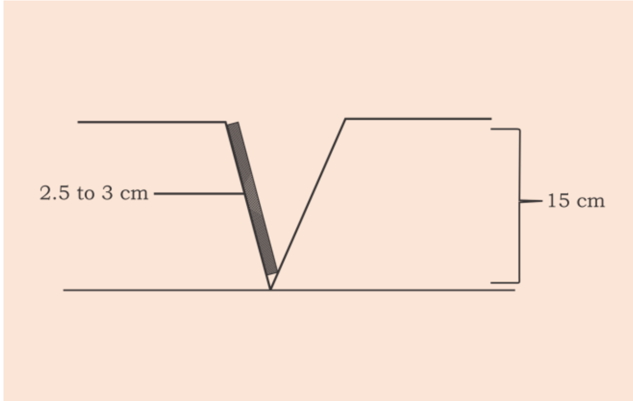


Fig. 3.4: V-shaped cut

v. Remove slices of uniform thickness of soil from top to bottom of the exposed face of V-shaped cut and place it in a clean open container.

vi. Mix the sample thoroughly with hands and remove foreign materials like grass roots, stones, gravels etc.

vii. After the samples have been properly collected from all the sampling spots, mix all the samples together to make a bulk.

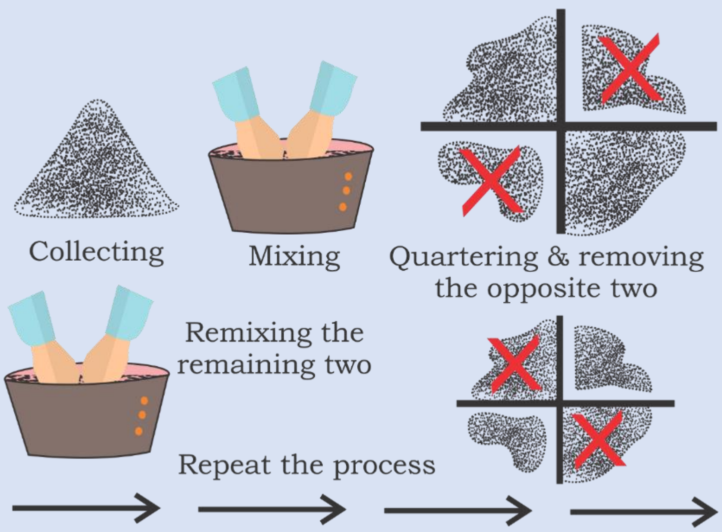
viii. Now reduce the bulk sample to half to one kg by employing the quartering technique. (Figure 3.5)

ix. Collect the final sample in a clean cloth or plastic bags.

x. Collected samples are now taken to the laboratory for processing and analysis.

Illustrative example of quartering technique

Quartering is done by dividing the bulk into four equal parts. The two opposite quarters are discarded and the remaining two quarters are remixed. The process is repeated until half to one kg sample is obtained.



The above process is explained with the help of following example:

Suppose, there are 10 sampling points in the field and you collect 800 g soil from each sampling point. So, the bulk sample will be 8 kg. Now by the process of first quartering you will be left with 4 kg of soil sample, subsequently in the next quartering you will be left with 2 kg of soils samples. But we need half to one kg of soil sample therefore, one more quartering is required. After this we are left with 1 kg of soil sample.

Fig.3.5: Quartering technique

I. Processing of soil samples

1. The finally collected and quartered samples are spread for drying on clean cloth or plastic or brown paper sheet at room temperature under shade.
2. The stone pieces, roots, leaves and other un-decomposed organic residues are once again removed from the samples.
3. Large lumps of sample (if any) are broken.
4. After air drying, the samples are crushed gently and sieved through a 2 mm sieve.

5. About 250 g of sieved samples are kept in properly labeled, clean sample bags or containers and stored for further testing and analysis.

II. Extraction and digestion of soil sample

Once the processing of collected soil samples is completed, they are brought to the laboratory for further analysis including the assessment of pH, EC and different nutrient contents present in it. pH and EC are directly measured using distilled water (soil water suspension), whereas nitrogen, phosphorus and potassium are measured using suitable chemical extractants (chemical solutions).

The process of extracting the nutrients in solution form is called extraction whereas digestion is a process of treating soil with concentrated acids like hydrochloric acid, sulphuric acids, nitric acids or perchloric acids in different ratios. These acids are used to break down complex chemical compounds in soil into simpler forms for determination of their elemental concentration for further analysis. These extracted solutions through the digestion process are used for the estimation of total nutrients

III. Analysis and interpretation of results

Different methods and procedures are followed for determination of soil properties and nutrient content with the help of specific equipment. The detailed information about these procedures is discussed in this Module.

Based on the analytical results of each soil property soils are grouped into different categories of low, medium or high based on which recommendations are made.

1.1.2 Water sampling and testing

The purpose of water sampling is basically to measure the nutrient constituents to assess the water quality for irrigation. Water is also tested and sampled for assessing the potability of drinking water but that is beyond the context of this book.

- **Name of the farmer: ....**
- **Location of the farm: ....**
- **Field number: ....**
- **Cropping history: ....**
- **Crop to be grown in the next season: ....**
- **Date of collection: ....**
- **Name of the sampler: ....**
- **Any other information: ....**

I. Water sample collection

- Collect water samples in a clean glass or plastic container which is thoroughly washed 3-4 times with distilled water and air dried.
- Always collect water samples in a running stream not in static condition. While collecting water sample from tube well or hand pump make sure that it had been operational 15-20 minutes prior to sample collection.
- If the water is turbid or loaded with impurities, it is filtered carefully before analysis.
- Collect water samples from the pond by avoiding 5 to 10 m distance from the boundary.
- The sampling bottles are kept tightly capped in a storage unit after labeling it properly.
- Add 2-3 drops of toluene to avoid microbial growth in the stored sample.

II. Water testing

Similar to soil testing, water testing is important to evaluate the quality of irrigation water. Water testing is mostly focused on the quantitative assessment of the soluble salts of nitrate, chloride, sulphate, carbonates and bicarbonates of sodium, calcium, magnesium and potassium. Sometimes irrigation water also consists salts of fluorine, boron etc. Water analysis is also carried out to study the harmful organic compounds and toxic heavy metals.

If a field is irrigated with poor quality water for a longer period of time, it deteriorates the soil health. Sometimes saline water stimulates crop growth because of higher amount of soluble nutrients present in it however, in the long run, use of poor quality or saline water in excess leads to accumulation of salts on the soil surface. This adversely affects the health of the soil. Therefore, it is always advisable to test water for its quality before using it for irrigation.

1.1.3 Basic criteria for assessment of irrigation water quality

In laboratory, we use four criteria for assessment of quality of irrigation water as shown in figure 3.6.

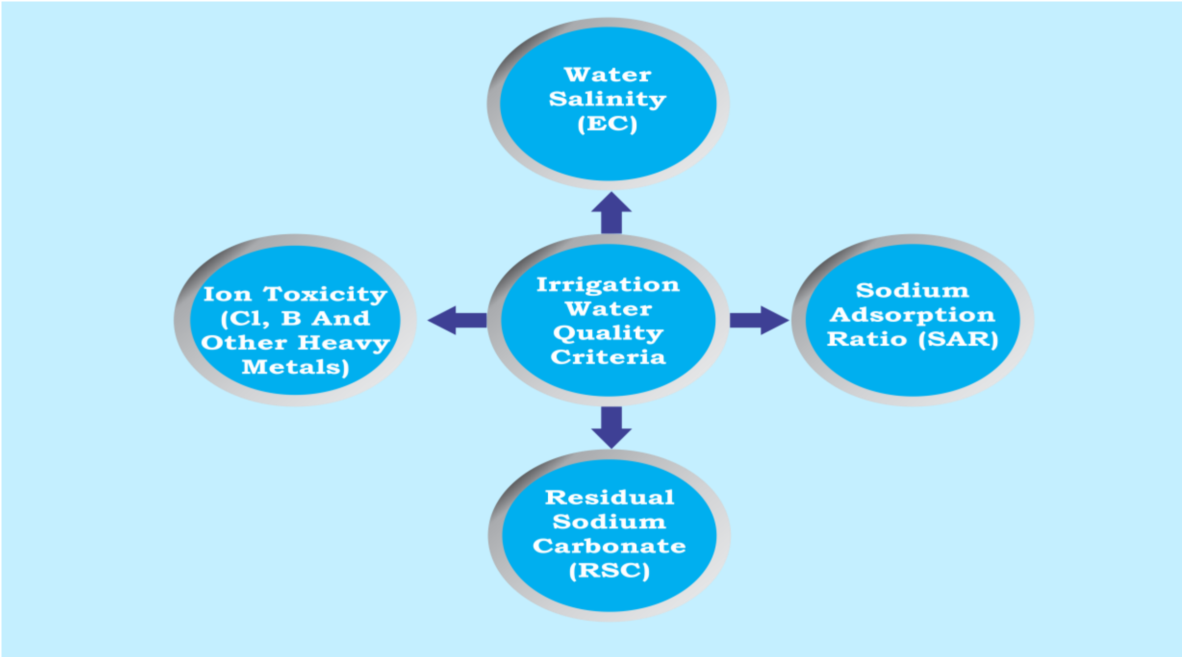


Fig. 3.6: Criteria for assessment of irrigation water quality

1.2 Soil and water testing facilities in India

Soil testing service in India started in the year 1955-56 with 16 soil testing laboratories (STLs). These STLs work in coordination with all the other soil testing laboratories in the country. The STL at ICAR-Indian Agricultural Research Institute (IARI), New Delhi is known as 'Central Laboratory for Soil and Plant Analysis' (Figure 3.7) among research and extension agencies.

Fig. 3.7: STL at ICAR-Indian Agricultural Research Institute (IARI), New Delhi

This laboratory is equipped with the state-of-the-art facilities such as ICP-MS (Inductively Coupled Plasma-Mass Spectroscopy), CHNS Analyzer, Atomic Absorption Spectrophotometer (AAS) and N-Analyzer etc.

In India, the number of soil testing laboratories is 1,087 of which 157 are mobile with a total analyzing capacity of 12 million soil samples annually. These laboratories analyze pH, EC, organic carbon, available N, P and K, secondary and micro-nutrients (Zinc, Iron, Copper, Manganese, B etc.) in soil and irrigation water quality. The Government of India (GOI) in collaboration with ICAR and different State Governments has established *Krishi Vigyan Kendras* (KVKs) in each district of most states in India which have the facility of soil and water testing.

Check Your Progress

Numerical 1: Mr. A collected 10 kg of soil samples from a field in Zig-Zag manner from 0-15 cm surface soil. How much soil Mr. A will remain in hand after repeated 3 times of quartering method of soil sampling drawing?

Solution: 1.25 Kg of soil sample.

Multiple Choice Questions

1. The STL at ICAR-Indian Agricultural Research Institute (IARI) also known as 'Central Laboratory for Soil and Plant Analysis' is located at:
   a) Mumbai
   b) Chennai
   c) New Delhi
   d) Bhopal
2. The basic purpose of soil and water testing is -
   a) Manure and fertilizer recommendation
   b) To maintain soil health
   c) Enhancing crop growth and economic return
   d) All of the above
3. Soil testing includes measurements of
   a) pH
   b) Primary (N, P and K) and secondary (Ca, Mg, S) nutrients
   c) Micronutrients (Fe, Mn, Zn, B)
   d) All of the above
4. Water analysis for agricultural purposes use the measurement of-
   a) Quality of water for drinking purpose
   b) Quality of water for irrigation purpose
   c) Quality of water for washing purpose
   d) All of the above

5. Soil sampling is taken in the field by-
   a) Zig-zag manner
   b) V shaped cut using Khurpi
   c) Both of the above
   d) None of the above

Fill in the Blanks

1. Soil testing service in India started in the year…………………
2. 2-3 drops of …………………is used for the control of microbial growth in the stored water sample.
3. Salts of nitrates and sulphate are source of elements ……… and ……….
4. Presence of bicarbonate and carbonates makes the soil …………
5. Full form of RSC is ………………………………….

True or False

1. A true representative soil sample means it is uniform mixture of different soil samples of the entire area.
2. Collect water samples from the pond by avoiding 5 to 10 m distance from the boundary.
3. Use of higher doses of fertilizer over long periods results in improvement in soil health.
4. Soil acidity is caused by excessive amount of soluble salt in the soil.
5. Presence of micronutrients in excess amount leads to improved quality of irrigation water.

Session 2: Instruments Used in Soil and Water Testing

In this session we will study about the different instruments and their working principles used to conduct soil and water testing. These instruments ensure accurate, reliable, and timely testing of soil and water samples.

2.1. Weighing balance

It is used for taking weight of soil samples or chemical reagents. It is usually placed in a solid surface base and is set to zero. The top of the instrument is covered with glass empanel with a sliding door on one of the sides for handling the soil or chemicals reagents. A high precision weighing balance can measure the weight up to the accuracy of 0.1mg. The assembly of a typical weighing balance is shown in figure 3.8.

> ***Calibration of an instrument***
>
> It is the process of setting or configuring an instrument to get accurate results in the acceptable range.

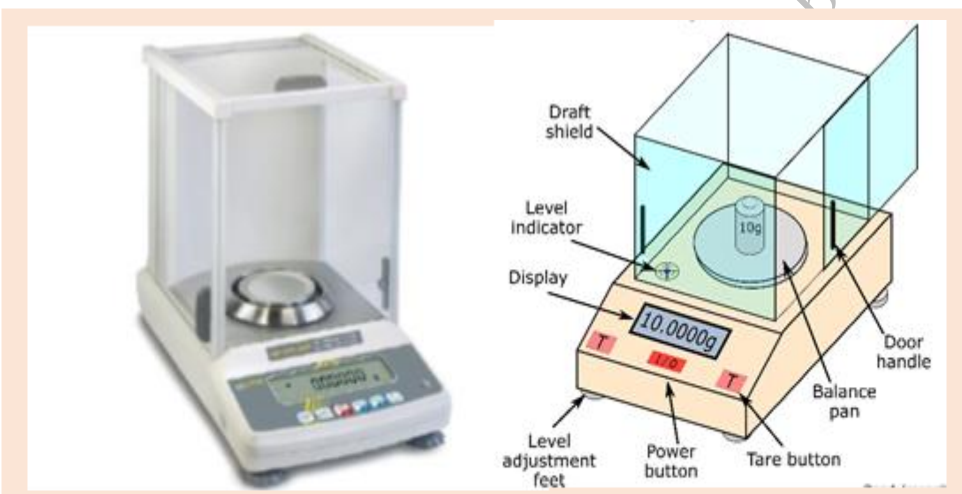


Fig. 3.8: Weighing balance and its schematic view

2.1.1 Calibration of weighing balance

The most important points to remember

- Keep the balance clean and tidy.
- Allow the balance to warm up to room temperature (25 ^{0}C) before use.
- Ensure frequent calibration to get consistent results to minimize errors and maximize precision in your measurements.
- Always use gloves and forceps while using the weighing balance.

2.1.2 Precautions

- Exposing the balance to corrosive materials, high temperature, water and dust leads to its damage and inaccurate results.

- Routine cleaning of balance with appropriate cleaning agents or organic solvents such as acetone, ethanol etc.
- Some cleaning agents may damage the balance surface. It is advisable to refer the service manual before using such cleaning agents.
- Plug the balance into a power surge protector.
- Do not leave any reagents on the balance weighing pan for an extended period of time.

2.2 Pressure plate apparatus

This apparatus is used to measure water retention in soil. The apparatus consists of an air tight metallic chamber in which porous ceramic pressure plate is placed where the sample is subjected to an air pressure above the atmospheric pressure. The pressure plate apparatus and its different components is shown in figure 3.9.

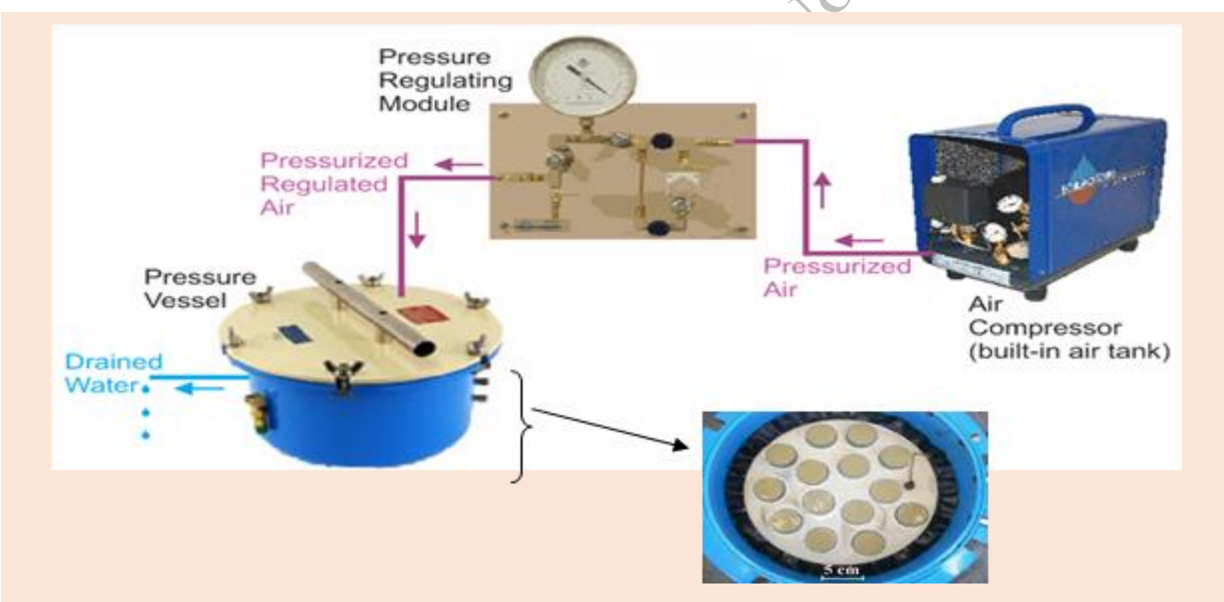


Fig. 3.9: Pressure plate apparatus and its different components

2.2.1 Working principle

The pressure plate apparatus is used to estimate field capacity, permanent wilting point and moisture content at different pressures. This apparatus consists of an air tight metallic chamber in which porous ceramic pressure plate is kept. The pressure plate and soil samples are saturated with water and placed in the metallic chamber. The required pressure of 0.33 or 15 bar is applied through its compressor. The water is allowed from the outlet till equilibrium point against the applied pressure is achieved. After that, the soil samples are taken out and are dried in an oven to determine the moisture content. Schematic diagram and view of pressure plate apparatus is shown in figure 3.10.

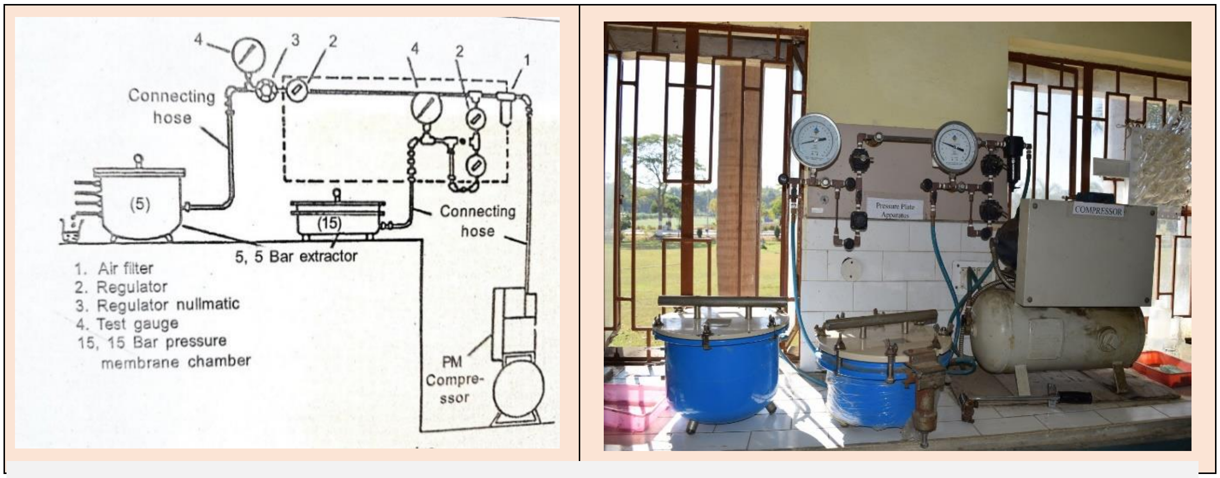


Fig. 3.10: Schematic diagram and view of pressure plate apparatus

2.2.2 Applications

- Pressure plate apparatus is used for measuring the water content of soil samples at field capacity and permanent wilting point.
- Determination of soil moisture retention characteristics in different types of soil.
- Assessing plant water requirement and irrigation scheduling.
- Assessment of plant water uptake and water storage.
- Determination of rate and quantity of water movement.

2.2.3 Precautions

- All the joints should be air-tight without any air-leak and it should be checked by pouring soap solution into the joints, with the help of cotton or wet cloth. Formation of air bubbles in soap solution indicates that the joints are not air tight.
- The pressure plate membrane normally should not be used more than once at higher pressure values.
- Plates are cleaned after every use by soaking in distilled water, gently brushing and rinsing, and then allowing them to air dry. No microbial inhibiters or chemical cleaning agents are used.

2.3 Yoder's apparatus

Distribution of aggregates i.e., structural stability of soil is important for determining the permeability of water in soil to decide the suitability of a soil for cultivation and its susceptibility to erosion.

The structural stability of soil is measured with the help of Yoder's apparatus. It comprises of four sets of nested sieves (from 5 mm to 0.1 mm or less) suspended from a bar which is oscillated by a shaft and crank system driven by an electric motor moving at approximately 1 oscillation per 2 sec. The nested sets of sieves move up and down through a vertical distance of about 3.8 cm submerged in drum. Sets of each sieve with different diameter are stacked in descending order. The Yoder's apparatus and its schematic diagram is shown in figure 3.11.

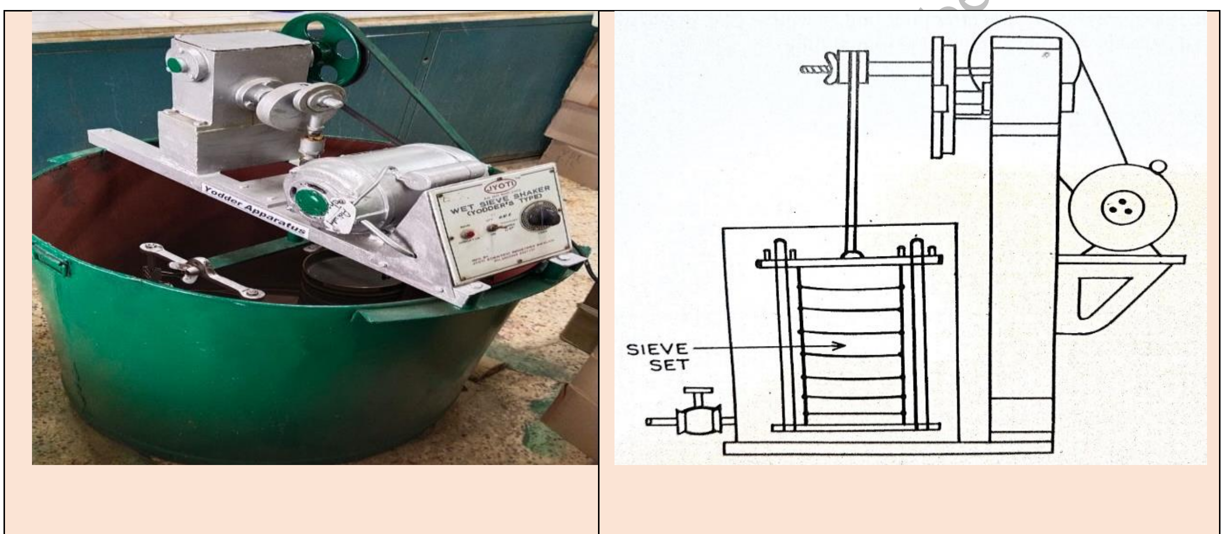


Fig. 3.11: Yoder's apparatus and its schematic diagram

2.3.1 Working principle

The basic principle in the wet sieving method is to place a given amount of soil aggregates in standard set of sieves in water for a given length of time. It is followed by collection of aggregate plus the coarse materials retained on each sieve and their weights. Finally, the aggregates retained in each sieve is determined in term of mean weight diameter (MWD), with following formula

Mean weight diameter (MWD): $\sum_{i=1}^{n} X_i W_i$

Where, n=6 (number of size fractions, i.e., 5.0 to 0.1 mm)

X= the mean diameter of fractions 'i'

W= the proportion by weight of a given size fraction of aggregate

2.3.2 Applications

- Distribution of aggregates of varying sizes or fractions (sand, silts and clay).
- Determination of the stability of soil aggregates to rain water or irrigation.
- Determine whether a soil surface seals or a curst develops in it.
- Indicates the structural permeability of soil to water.
- Determining suitability of soil for farming.
- Also useful in studying soil erosion.

2.3.3 Precautions

Avoid the inclusion of primary textural particles (sands or gravels).

2.4 Electrical oven

It is an electrical device used in laboratories for physical, chemical and biological analysis.

2.4.1 Working principle

Electrical oven is used for rapid drying of soil samples and dry heat sterilization of the different materials. The thermostat controls the temperature of the oven. An air circulating fan helps in uniform distribution of the heat inside it. These are fitted with adjustable wire mesh plated trays or aluminium trays, as well as indicators and controls for temperature and time. The temperature range in ovens is 50-250°C. The most common time-temperature relationships for sterilization with hot air oven are; 170°C for 30 minutes, 160°C for 60 minutes, and 150°C for 150 minutes or longer depending up the volume. Only remove the contents from the oven when the temperature has reduced down to 50°C. An electrical oven and its schematic diagram is shown in figure 3.12.

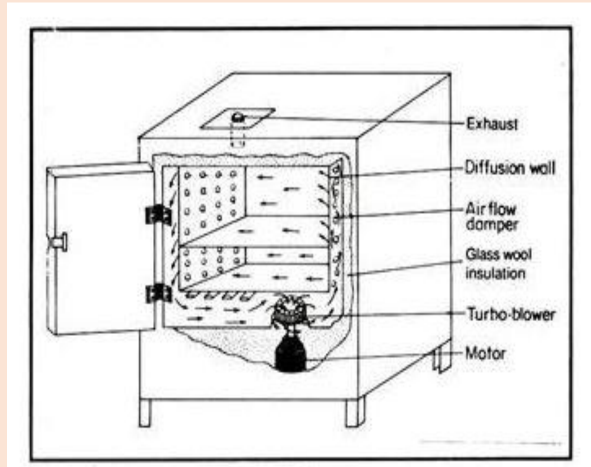


Fig. 3.12: Electrical oven and its schematic diagram

2.4.2 Applications

- For sterilization of glassware.
- For drying of samples
- For determination of moisture content
- Determination dry weight mass of the sample.

2.5 pH meter

pH is a measure of the H^+ ion concentration in a solution and it is measured on a scale of 0 to 14. Soil pH is usually measured as soil-water suspension by using glass electrode pH meter.

2.5.1 Working principle

This instrument measures the voltage developed by the combination of a glass electrode and a reference calomel electrode. It is calibrated to measure the voltage in terms of pH units. Actual pH readings are obtained by calibrating the instruments with buffer solution of known pH values. pH measurement of the soil is carried out with soil-water suspension in the ratio of 1:2.5 at room temperature. Depending on the hydrogen (H+) or hydroxyl (OH^-) ions concentration (soil pH) in soil is categorised as acidic, basic or neutral (Fig 3.13 a,b).

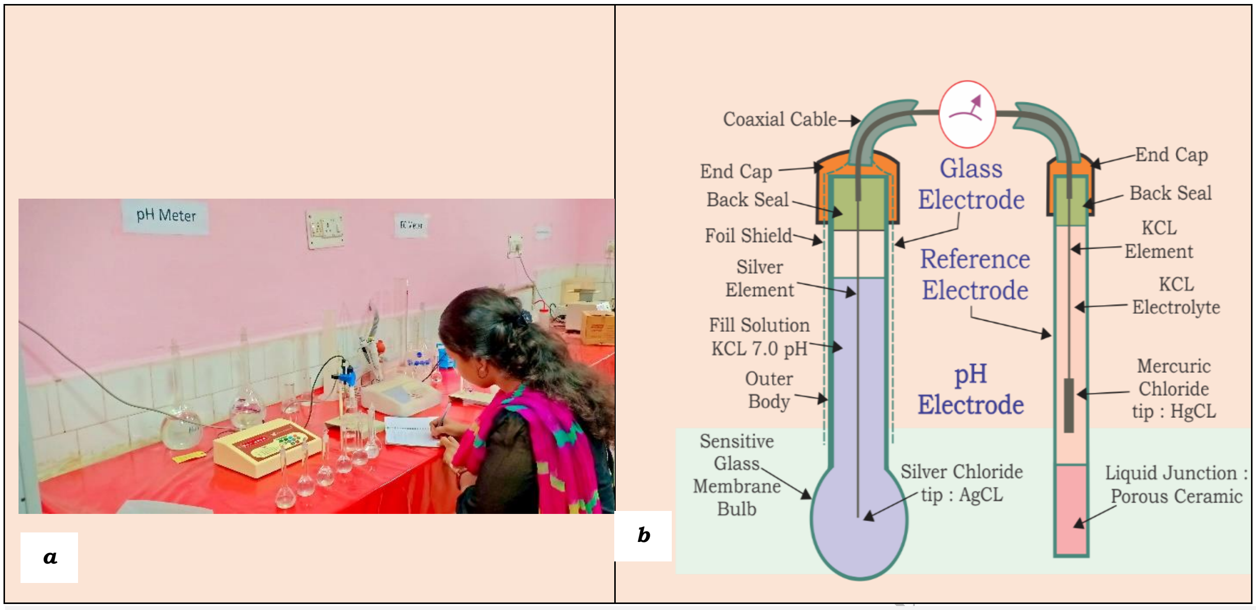


Fig. 3.13 a: A researcher using a pH meter in a soil and water testing lab

Fig. 3.13 b: Schematic diagram of a pH meter

2.5.2 Applications

- This helps in determining the soil pH thereby ascertaining whether to add nutrients or not.
- Recommendation of fertilizer and manure application.
- Ascertaining the soil pH provides the most rational basis for managing soil for selective agricultural crops, horticultural crops, pasture cultivation, forestry, etc.

2.6 Electrical conductivity meter

Electrical conductivity (EC) meter measures the salinity of a liquid or soil samples.

- An EC meter consists of an alternating current (AC) Wheatstone bridge, a primary element of conductivity cell and null balance indicator in the conductivity meter.
- The test solution is filled in the conductivity cell, which is usually made of two platinum sheets embedded in glass so that the surfaces facing each other remain exposed.
- In order to increase the sensitivity of the measurement, one or two stages of amplification are provided before feeding the signal to the null balance (figure 3.14).

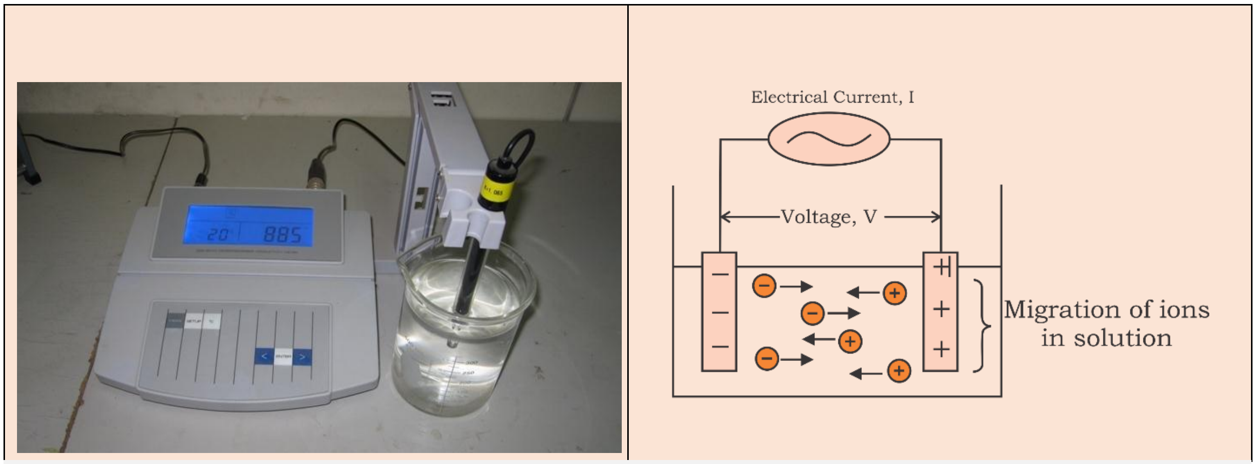


Fig. 3.14: Electrical Conductivity Meter

2.6.1 Working principle

The electrical conductivity is a measure of ability of salt ions in a solution to carry electric current by their migration under the influence of an electric field. Like a metallic conductor, solutions also obey Ohm's law. Increase in temperature promotes dissociation of salts with a consequent rise in conductivity. EC is expressed as dS m^{-1} (deci-Siemens per metre which is equivalent to the unit m mhos cm^{-1}).

2.6.2 Applications

- To judge the soluble salts in soil and water samples.
- It is one of the common soil management interventions for the salt affected soils.
- It is precise and rapid for estimation of salts in soil and water samples.

2.6.3 Precautions

- EC meter should be placed at room temperature (25 ^{0}C), otherwise the conductivity reading will be erroneous.
- Before using the instruments, the conductivity cell is kept in distilled water for 24 hours.
- If the instruments in not in use, keep the cell in distilled water.
- The conductivity cell must be cleaned properly for accurate readings.
- The cell is rinsed with distilled water before placing it in a sample solution.

2.7 UV-Visible spectrophotometer

The UV-visible spectrophotometer consists of four basic components

(i) A light source, usually a tungsten filament lamp or Hydrogen-Deuterium lamp.

(ii) A monochromatic filter (prism or grating) as dispersion device to separate out the analytical wavelength from the other radiations.

(iii) A sample cell or absorption cell through which the light is passed.

(iv) A detector for measuring light intensity of the emitted radiation (figure 3.15).

> ***Do you know!***
>
> Ultra violet (UV) light is the main cause of skin cancer and falls in the wavelength of 200-400 nm.
>
> The human eye can detect light in the wavelength range of 400-700 nm. This is known as visible light.
>
> The process of photosynthesis takes place in visible light. (400-700 nm).

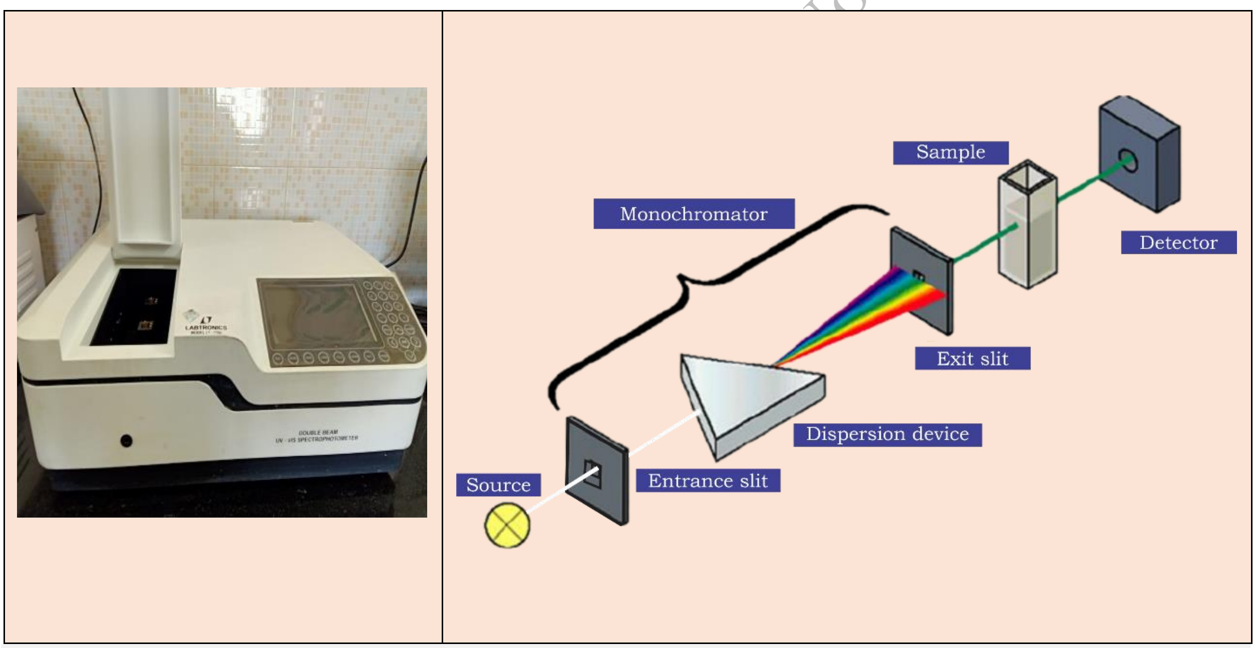


Fig. 3.15: UV-visible spectrophotometer and its schematic diagram

2.7.1 *Working principle*

- It is based on the measurement of relative absorption or transmission of ultraviolet or visible light by chemical compounds under study.
- Atomic absorption spectrochemistry is based on Beer-Lambert's law which states that the absorbance of light spectra of a solution is directly proportional to the concentration of the absorbing compounds in the test solution and the path length.

2.7.2 Applications

- It is routinely used in the analytical chemistry laboratory for the quantitative determination of different chemicals.
- It is one of the important instruments for microbiological analysis.
- Used for determination of impurities in organic molecules as well as for their molecular weight determination.
- Qualitative characterization of aromatic compounds.

2.7.3 Precautions

- Protect the instrument from mechanical shocks and vibration at the surface.
- The instrument should be warmed up with light source sufficiently before use as per its manual.
- Consult a competent engineer in case of any fault of the instrument.
- An automatic voltage stabilizer along with AC supply is required for optimum function of the instrument.
- Always clean the instrument with soft tissue paper and place the cuvette gently in order to avoid scratches.

2.8 Flame photometer

The gas flame acts as a source of excitation for atoms. This principle has been used extensively under the name of 'Flame photometery' which is used for the measurement of alkali (Na & K) and alkaline earth metals (Ca & Mg).

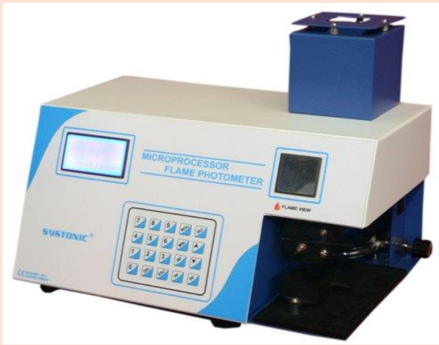
When a solution of a salt is injected into the flame, the salt breaks down into the component atoms due to high temperature. The energy provided by the flame excites the orbital electrons to higher energy levels. When these electrons return to their ground state, they emit as characteristics radiation.

The flame photometer consists of three parts (Figure 3.16):

(i) Atomization assembly: It consists of a nebulizer (atomizer) to produce a fine mist from the solution and a burner which vaporizes the analyte in atomized form.

(ii) Monochromator: It is a filter or a prism that separates out the analytical wavelength from the other radiations.

(iii) Photometric system: It is used for measuring the intensity of the emitted radiation.



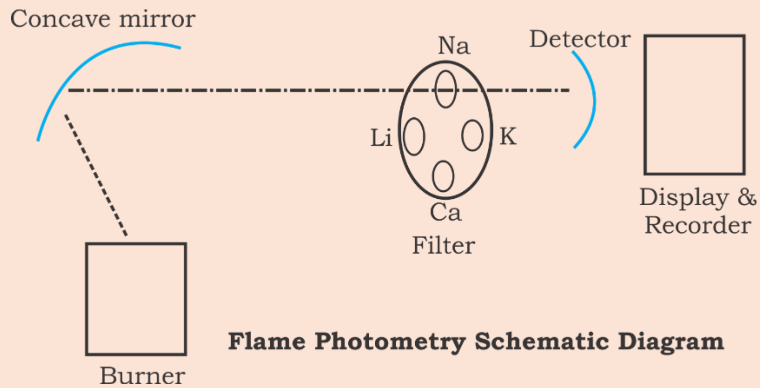


Fig. 3.16: Flame photometer and its schematic diagram

Modern flame photometer is operated in fully online mode with the help of computer software and different operation parameters and can be set through keyboard commands whereas ordinary instruments is used manually.

2.8.1 Working principle

- Flame emission spectrophotometers are designed to measure the intensity of the characteristics line emitted from the excited atoms or ions of the element to be determined, which involves measurement of the absorption of radiant energy by excited atoms.
- Each excited single atom emits one quantum of radiation emitted from steady and non-luminous flame which is proportional to the number of atoms of the particular element in the flame i.e. its concentration.
- The concentration is directly related to the content of the element in the test solution. The concentration of the analyte in the sample is to be computed from the calibration curve.

2.8.2 Applications

- Used for measurement of alkali and alkaline and alkaline earth metals
- Quantitative and qualitative analysis of elements.

2.8.3 Precautions

- Follow the user's manual for proper handling of the instrument. For switching on the instrument, turn on the gas supply first and then the burner
- Keep the standard and the samples free from any suspended materials to prevent clogging of the instrument and nebulization assembly.

- Do not feed highly concentrated acids and salt solutions.
- Maintain a constant supply of air-gas mixture to the burner.
- Do not leave the flame unattended.
- Periodically replace the pressure tubing of the fuel gas.

2.9 Atomic absorption spectrophotometer

Atomic absorption spectrometer (AAS) is a very sensitive instrument used for the determination of metals in a variety of samples at the ppb (parts per billion) level.

The atomic absorption phenomenon involves a detection of the reduction of the intensity of optical radiation subsequent to its passage through a cell containing gaseous state of the atoms.

The AAS (Figure 3.17 a, b) typically consists of:

(i) A light source, called a hollow cathode lamp (HCL), which emits specific wavelengths of light that are ideally absorbable by the analyte.

(ii) An 'atom cell', which serves to convert the samples into gaseous atoms that can absorb light from the HCL.

(iii) A 'detection system' that serves to isolate and quantify the wavelengths of interest, and

(iv) A recorder and display with a computer aided control for instrument operation and data processing.

Usually, samples are converted to aqueous solutions by digestion procedures to minimize interferences and provide optimal precision and accuracy.

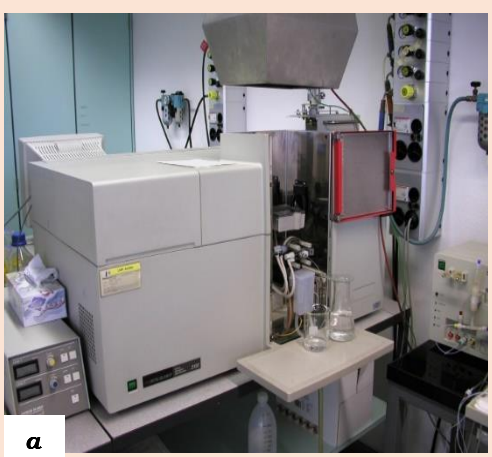


Fig. 3.17 a: Typical AAS assembly

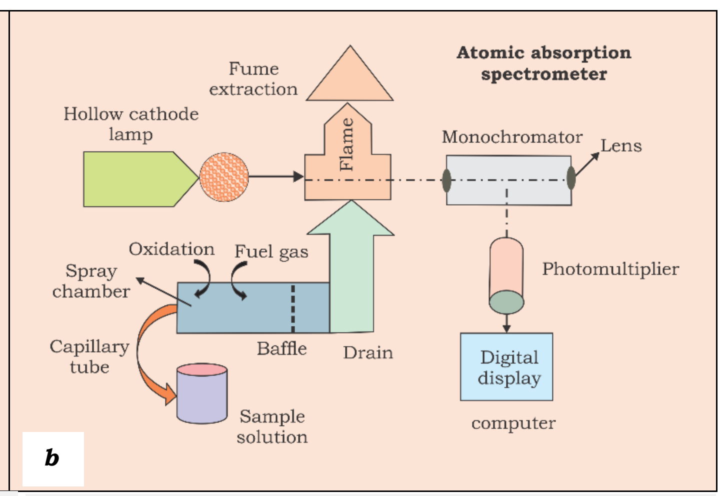


Fig. 3.17 b: Working principle of AAS

2.9.1 Working principle

- The basic principle of analysis in AAS is that the sample in form of a homogeneous liquid is aspirated into a flame where "free" atoms of the elements are created.
- A light source (hollow cathode lamp) is used to excite the free atoms formed in the flame by the absorption of the electromagnetic radiation (Figure 3.18).

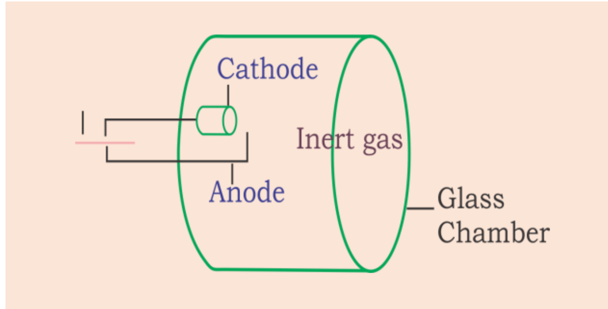


Figure 3.18: Basic assembly of Atomic Absorption Spectrophotometer

- The decrease in energy (absorption) is measured which follows the theory of Beer- Lambert's law i.e., the absorption is proportional to the number of free atoms in the ground state.

2.9.2 Applications

- It is used for quantitative analysis of metal elements in water, soil and plant material.
- It is very useful instrument in the case of health care services for analysis of ionic metals elements in blood, saliva, urine samples causing different types of toxicity or disease.
- It is also used for the quality testing of any product for assessing metal elements such as copper, nickel, and zinc and toxic heavy metals like lead, chromium, cadmium, arsenic and mercury etc.
- The assess the water quality for safe use in irrigation or drinking purpose.

2.9.3 Precautions

- Acetylene cylinder should always be used in a vertical position to prevent liquid acetylene entering the gas line.
- Acetylene cylinder should not be run at a pressure at a lower than 500 kPa (70 Psi). Never operate acetylene line above 100 kPa (15 psi). At higher pressure acetylene can spontaneously decompose or explode.
- Never run the nitrous oxide -acetylene flame without 'red feather' visible, or with less than 5 flow units of acetylene.
- Do not leave uncovered containers of the volatile organic solvents near the uncovered flame.

- Do not look at the flame without the aid of safety eye glasses.
- Do not leave the flame completely unattended.
- Do not ignite the flame if the air flow is below 6 flow units.
- Do not adjust the air (or N_2O) and gas supply to alter the sensitivity of the instruments after the calibration of the instrument.
- A power back-up is highly desirable for operating AAS as a power failure leads to fast conversion to yellow flame, which in turn produces a lot of carbon.

2.9.4 Steps in switching Off AAS

- Turn off the gas supply from the cylinder first.
- Wait for the extinction of the flame and then turn off the fuel control knob.
- Turn off the air compressor and fuel support knob.
- The shut-down sequence for a nitrous oxide-acetylene flame involves first charging over to an air-acetylene flame and then extinguishing it.
- Switch off the instrument.

Check Your Progress

Multiple Choice Questions

1. Electrical oven is used for
   a) Sterilization of glassware
   b) Cleaning of glassware
   c) Measurement of temperature
   d) Drying the chemicals
2. Pressure plate apparatus is used to measure
   a) Air pressure
   b) Soil structure
   c) Soil texture
   d) Soil moisture content
3. UV-visible Spectroscopy follows the principle of
   a) Lambert-Beer's law
   b) Stroke's Law
   c) Graham's Law

d) Newton's law

4. The light source used in UV visible Spectro-photometer
   a) Tungsten filament
   b) Hydrogen-Deuterium
   c) Both
   d) None of the above
5. Metal ions content is determined by which of the following instrument
   a) Flame photometer
   b) EC meter
   c) Spectrophotometer
   d) AAS

Fill in the Blanks

1. A highly precise weighing balance keeping room temperature should be ……………….
2. The element used as internal standard element in flame emission spectrophotometer is ………………
3. The concentration of the analyte or element in the sample is to be computed from the ……………
4. An energy state with a relatively large amount of energy associated with it is called………
5. Lead, chromium, cadmium and arsenic are called ……………. Element.

True or False

1. A free atom of elements created when it not absorbs some energy from a flame
2. A high concentrated metal solution having low absorption of light.
3. pH meter is an instrument with the combination of a glass electrode and a reference calomel electrode
4. ppb (parts per billion) is lesser than ppm (parts per million).
5. Temperature working range cover in Electric oven is 50-250°C.

Session 3: Important Soil and Water Testing Parameters

Soil and water testing is carried out to collect exact information about various soil physio-chemical properties such as texture, structure, pH, electrical conductivity, acidity, salinity, sodicity or alkalinity and available macro and micronutrient status in relation to essential elements for crop growth and productivity.

The use of chemical fertilizers and manures has led to higher food production these days. However, imbalanced use of fertilizers and poor-quality organic manures over a considerable period of time adversely impacts the soil health. Thus, the soil and water testing on regular basis has become essential to evaluate soil fertility status and provide relevant prescription of fertilizer and manures.

3.1. Importance of soil and water testing parameters for quality assessment

Soil quality measurement cannot be judged based on a single parameter. A number of factors are needed to assess the soil quality. The major reasons for poor soil health include

a) Wide gaps between nutrient demand and supply from the soil.

b) Imbalance in fertilizer application.

c) Emerging deficiency of secondary and micronutrients due to improper use of inputs such as water, fertilizers, pesticides, manures and other organic inputs.

d) Development of acidity salinity and alkalinity.

e) Soil pollution and heavy metal toxicity.

f) Disproportionate growth of soil organisms (vi) deforestation and industrialization.

Important soil and water testing parameters are essential for assessing the quality of nutrient supplying capacity of the soil and water. These parameters are closely related to nutrient availability, plant growth, yield and nutrient dynamics in the given environment. The most important parameters include pH, electrical conductivity, organic carbon, available macro and micronutrients (Cu, Zn, Fe, Mn and B), carbonates (CO_3^{2-}) and bi-carbonates (HCO_3^{-}). Boron and chloride are especially used for quality assessment in water.

i. pH: It is used for characterizing soil from the standpoints of nutrient availability, soil structure, permeability etc. pH is also used for assessing the suitability of soil for different agricultural crops, pastures, forestry etc.

Extremely high and low pH adversely affects soil properties as they are linked with the nutrient availability and plant growth which in turn reflects on the soil health. Management practices for soils having different pH and their suitability for crop growth are presented in Table 3.1.

Table 3.1. Soil Types, their pH and Management

pH	Soil types	Inferences	Suitable Crops
<6.5	Acidic	Require liming	Tea, Rice, Millets, Potato etc.
6.5 to 7.5	Normal	No treatment	Ideal for all agricultural crops
7.5- 8.5	Saline/calcareous	Requires leaching of soluble salts	Sesbania, Rice, Sugarcane, Oats, Berseem and Plantation crops (Coconut, Areca nut etc.)
>8.5	Alkaline	Requires gypsum amendments	Sugar beet, and different Grasses (Bermuda, Karnal, Para grass)

ii. Electrical conductivity (EC): The soluble salt content in the soil and water are measured by its electrical conductivity. Determination of EC is very important in heavily-fertilized and salt affected soils. In such soils, salts accumulate in quantities which are detrimental to soil health and overall crop production. Table 3.2 presents the salinity scale, salinity level and the effect of salinity on crop plants.

Table 3.2. Salinity Scale and Plant Responses

Salinity scale	EC (ds m^{-1})	Salinity level	Effect of crop plants
A	0-2	Non saline	Negligible
B	2-4	Slightly saline	Affect yields of sensitive crops
C	4-8	Moderately saline	Yields of many crops are affected.
D	8-16	Strongly saline	Only tolerant crops like rice, barley, sorghum, canola, maize, berseem, cotton, sudan grass are not affected.
E	>16	Very strongly saline	Only a few very tolerant crops like sugarbeet, coconut, tobacco, bermuda grass, karnal grass, rhodes grass are not affected.

iii. Organic carbon: Soil organic matter is the reservoir of carbon in soil and its determination is done for determining the index of soil nutrient availability and soil quality. The carbon to nitrogen (C: N) ratio in different soils vary which directly influences the nutrient mineralization in the soil. The organic carbon content of the soil is measured by colorimetric method through oxidization with dichromate-sulphuric acid mixture. The titration method is used to measure the direct amount of carbon oxidized by measuring the intensity of green color of the chromium sulphate formed. Table 3.3 gives the status of organic carbon in a soil sample.

Table 3.3: Interpretation of Organic Carbon in a Soil Sample

Organic carbon (%)	Status of Organic Carbon
<0.50	Low
0.50-0.75	Medium
>0.75	High

iv. Available macronutrients: The available macronutrients include N, P, K and S. Their content has major contribution in soil fertility. Assessment of soil fertility status involves an estimation of its available nutrient status, usually at 0-15 cm soil depth. This exercise is commonly referred as soil testing and used by farmers around the world to arrive at optimum fertilizer recommendation rate. The need of measurement of "available" nutrients arises because only a small fraction of the total nutrient content is in plant-available form. Soil tests are calibrated by correlating them with crop response and the results form the basis for making fertilizer recommendations.

a. Available N: The chemical analysis of NH_4^+ and NO_3^- is the mineral fraction of N which is required for assessing available nitrogen status of the soil. The nitrogen availability is the basis of finding soil N critical level, which rationalize the use of efficiency of N-fertilizer in soil. Table 3.4 gives the Interpretation of the available N in soil samples.

Do you know!

N is most deficient nutrient in the soil of India

Table 3.4: Interpretation of the Available N in Soil

Amount of N (kg/ha)	Status of available N
<240	Low
240-480	Medium
>480	High

b. Available P: In soil testing, the available P content is the important component of critical limit in recommendation of fertilizers. The critical limits eventually help in predicting crop response to the applied P. Table 3.5 gives the interpretation of the available P in the soil.

Table 3.5: Interpretation of the Available P in the Soil Sample

Amount of P (kg/ha)	Status of available P
<11	Low
11-22	Medium
>22	High

c. Available K: The available form of K is considered that supply of K which is available to the plants on a loamy soil, when exchangeable K is greater than 0.025 of the total K. Table 3.6 gives the interpretation of the available K in the soil samples.

Table 3.6: Interpretation of the Available K in the Soil Samples

Amount of K (kg/ha)	Status of available K
<110	Low
110-280	Medium
>280	High

d. Available S: Estimation of available S is very essential for different integrated fertilization recommendation. Estimation of available S is mainly done in S-deficient areas and for certain crops whose requirement for this nutrient very high, often exceeding that of P. Soils having <10 ppm S are said to be deficient in S.

Available micronutrients

The micronutrients include Cu, Zn, Fe, Mn and B. The deficiencies of multiple micronutrients lead to poor crop yield and in some cases failure of crop. The deficiency and toxicity of micronutrients falls under very narrow range. For example, Fe concentration of 4.5 ppm is good for plant growth but becomes toxic above 5.0 ppm.

Analysis methods of available macronutrients vary depending on the soil types. In general, the procedures suitable for acidic soils are not suitable for the alkaline soils. Even organic soils require an entirely different soil testing procedure. Therefore, it is important to know the suitability of a particular test procedure for estimation of available micronutrients.

a. **Available copper (Cu):** Available form of Cu helps in knowing the incidence of Cu deficiency, toxicity, and fertilizer recommendation. The availability of Cu decreases as it readily interacts with other nutrients like N and S to form complexes.

b. **Available zinc (Zn):** As available Zn makes complexes with other elements like P, the availability of P is decreased. This phenomenon is called Zn-induced P deficiency. Predicting Zn availability in the soil is very difficult because its availability is affected by soil and environmental factors. The availability of Cu and Zn is soil relatively low as they are found in complex form in soil.

c. **Available iron (Fe):** The available Fe content in soil is mostly influenced by soil pH, soil textural class and cation exchange capacity.

d. **Available manganese (Mn):** Estimation of available Mn content provides information about the deficiency, adequacy or toxicity of Mn in soil. The available Mn is estimated in soils with low pH whereas exchangeable Mn is best estimated soils with high pH. The Mn toxicity in the soil negatively interacts with the Fe content of the soil. Therefore, high amounts of available Mn is predicted if Fe availability is low and vice versa.

e. **Available Boron (B):** The knowledge of water-soluble B in soils is of considerable agricultural importance. B deficiency occurs within narrow limits. B interacts with calcium by precipitation as calcium metaborate under extreme soil and climatic conditions.

Parameters for Irrigation water Quality testing

i. **Carbonates and bi-carbonates, boron and chloride in water**

a. **Carbonate and bicarbonates:** The carbonate (CO_3^{2-}) and bicarbonate (HCO^-_3) anions are important parameters which adversely affect the soil health and crop productivity. The presence of these anions in water is a very important criteria for judging the quality of irrigation water. As the carbonates and bi-carbonates are dominantly present in alkaline conditions it indicates presence of Ca and Mg in the soil and water. This condition leads to changes in soluble sodium concentration in the irrigation water causing sodium (Na) toxicity as well. The residual sodium carbonate (RSC) is used to evaluate the quality of irrigation and is expressed in meL^{-1} (milliequivalent per liter) (Table 3.7).

$$RSC = (CO_3- + HCO3-) - (Ca^{2+} + Mg^{2+})$$

Table 3.7: Water Quality Assessment Based on RSC Values

RSC values (me L^{-1})	HCO_3^- (me L^{-1})	Water quality
<1.25	<1.5	Can be used safely
1.25-2.5	1.5-8.5	Can be used with certain management practices
>2.5	>8.5	Unsuitable for irrigation purpose

b. **Boron (B):** For quality rating of irrigation water, samples are not usually tested for B content. However, saline water of arid and semi-arid regions may have high concentration of B, which could be toxic depending upon the type of the minerals present in soil and the nature of soil strata though which the water passes to reach the groundwater. This water contains excessive amounts of boron, which is unsafe or toxic to plants (Table 3.8). In fact, the margin between toxicity and deficiency limits of boron is very narrow and hence water samples suspected to be containing high B content should be tested and classified accordingly.

Table 3.8: Water Soluble B Content and Crop Suitability

Water Soluble Boron (ppm)	Status	Crop suitability
<0.7	Low	Crops can grow (safe)
0.7-2.0	Medium	Moderately safe
>2.0	High	Unsafe

c. **Chloride (Cl):** Chloride ions are highly soluble in the water, but the amount is often very low in natural waters or rain water. The content of chloride in the water increases due to excessive evaporation in the areas of arid and semi-arid regions and also builds due to chloride salt bearing minerals. However, their content can also be assessed by the electrical conductivity values. The chloride content in water measures its quality and crop suitability (Table 3.9).

3.9: Chloride Content in Water and Crop Suitability

Chloride concentration (me/L)	Status	Irrigation Water quality
<4-7	Low	Good to excellent water
7-10	Medium	Marginally suitable
>10	High	Unsuitable for irrigation

Check Your Progress

A. Multiple Choice Questions

1. Salinity scale of a soil is measured with
   a) Soil pH
   b) RSC
   c) Boron content
   d) EC
2. A soil having the pH between 6.5 to 7.5
   a) Ideal for fruits crops
   b) Ideal for vegetable crops
   c) Ideal for cereals
   d) Ideals for all crops
3. The EC value is > 4.0 dSm-1 is termed as
   a) Alkaline
   b) Saline
   c) Saline-alkaline
   d) Acid soil
4. Available primary macronutrient of the soil includes
   a) N
   b) P
   c) K
   d) All of the above

5. A soil with medium N content the available N content (kg/ha) in the soil ranges between
   a) 240-280
   b) 11-22
   c) 110-280
   d) None of the above

B. Fill in the Blanks

1. Non saline soil having the EC (dS m-1) values ......
2. High organic carbon in soil have ....% of carbon
3. A high available potassium rich soil has the available K (kg/ha) ....
4. Low water soluble boron content (ppm) .... is safe for crops.
5. Chloride of the soil is developed in the ....and .... region

C. True or False

1. Soil Quality is judged by single parameter i.e. soil pH
2. pH of the Acidic soil types is low (<6.5)
3. Organic carbon is carbon present in soil organic matter.
4. Liming materials are used to reclaim the acidic soil
5. Soils, having <10 ppm S, are said to be deficient in Sulphur.

Module 4
Safety Considerations in Laboratory

Module Overview

Soil and water testing are important techniques which are used for research and advice on recommended dosage of various fertilizers for different crops. To get accurate results from the analysis of soil and water samples, we follow standard procedures and techniques. These techniques are termed as "Good Laboratory Practices" (GLPs). In this Module, along with the GLPs we will study the different safety measures and procedures which are followed while working in a soil and water testing laboratory

Learning Outcomes

After completing this module, you will be able to:

- Explain the principles of Good Laboratory Practices (GLP), including standard operating procedures, quality control, and documentation to ensure accuracy, reliability, and reproducibility of laboratory results.
- Describe the key aspects of occupational health and safety in a laboratory setting, including hazard identification, risk assessment, use of personal protective equipment (PPE), and emergency response procedures to maintain a safe working environment.

Module Structure

- Session 1: Good Laboratory Practices
- Session 2: Occupational Health and Safety

Session 1: Good Laboratory Practices

The information about soil and water quality from different regions of the world is required for conservation and improvement of the quality of soil and water and also for fertilizer recommendation to enhance the crop production. To get consistent data it is essential to follow GLPs. It includes all measures to ensure the accuracy in analysis for maintaining the uniformity in soil and water testing laboratories worldwide. GLPs include sample collection, characterization of soil and water samples, uniform lab analysis and safety measures to be taken inside the laboratory.

1.1 Advantages of GLPs

GLPs refer to a quality system for ensuring exact output of soil and water quality management controls needed in different research laboratories.

- Ensure representative sample collection.
- Fulfill all laboratory safety measures.
- Reliable estimation of soil and water.
- Generation of high-quality test data.
- Mutual acceptance of data amongst stakeholders and clients.
- Increases public confidence and recommendations.
- Reproducibility of the data.
- Promote international acceptance and reputation.

Thus, adoption of GLPs ensure the following aspects as shown in figure 4.1

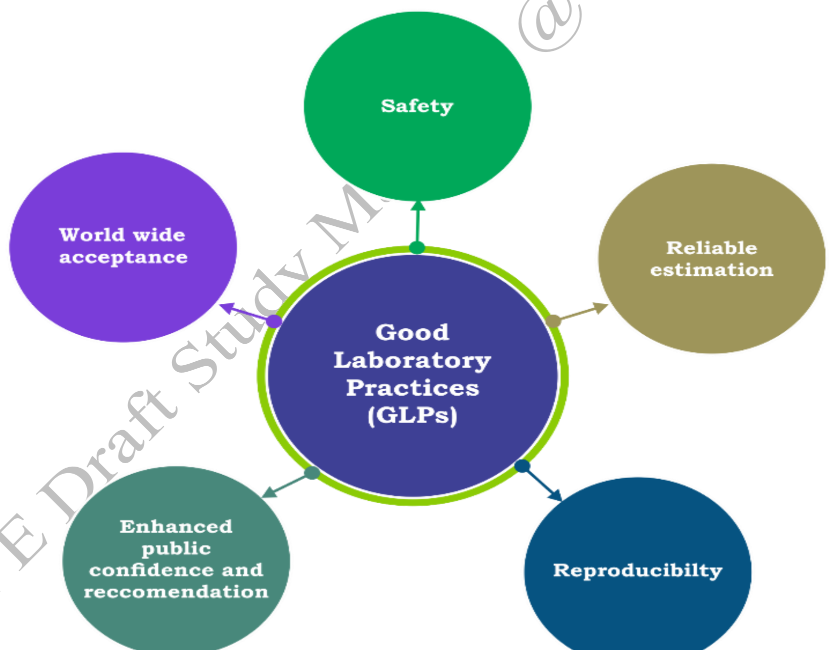


Fig. 4.1: Characteristics of GLPs

Do you know!

Good Laboratory Practices (GLPs) were initiated as a reaction to the different malpractices in the laboratories, which were conducting safety experiments of medicines in an unethical way in the USA in the 1970's. GLP was first created by United States Food and Drug Administration (USFDA) in 1976. In 1981, the Organization for Economic Cooperation and Development (OECD) provided GLP principles that are international standards and applicable to all laboratories across the globe.

GLP includes "FAIR"
laboratory data management

F: Findable
A: Accessible
I: Interoperable
R: Reusable

1.2 Components involved in GLPs

GLPs include several components, which together provide accurate and reliable results that are acceptable worldwide. The different components of GLPs are depicted in the Fig. 4.2

COMPONENTS OF GLPs

Personnel	Documentation	Facility	Test and Control Articles (Calibration and analysis)
• Laboratory Manager • Laboratory Technician • Quality check and assurance	• Standard Operating Protocols (SOPs) • Reports • Archives	• Laboratory Operations • Equipment • Reagents • Storage	• Calibration of equipment • Standard reference materials • Sample Charecterisation • Storage

Fig. 4.2: Different components of GLPs

1.3 Soil and water testing laboratory

The soil and water testing laboratory offers soil, plant, manure and irrigation water analysis services to the farmers, students and other stakeholders. Regular or advanced level of trainings for soil and water testing are also commonly provided by such laboratories to the different stakeholders. The vocational students in the area of soil and water testing may be taken to such laboratories for their practical. One such prominent laboratory is at the ICAR-Indian Institute of Soil Science (IISS) Bhopal, Madhya Pradesh (figure 4.3). The ICAR-IISS is actively engaged in basic and strategic research in the field of Soil Science in India.

Fig. 4.3: View of ICAR-Indian Institute of Soil Science, Bhopal

1.4 Maintaining safe and clean working environment in a soil and water testing laboratory

1.4.1 Laboratory safety

In soil and water testing laboratory, one has to maintain personal hygiene and ensure safety of others working in the same lab. The most important requirements that should be fulfilled, in addition to skilled staff, are the supply of adequate equipment and working materials, the presence of suitable housing, and the enforcement of proper safety measures.

1.4.2 Laboratory set-up

Food and Agriculture Organization (FAO) of United Nations has suggested that the general lay-out of a laboratory should preferably have two separate blocks as shown in the figure 4.4. Samples are transferred from the storage house to the scientific block through a passage or buffer room.

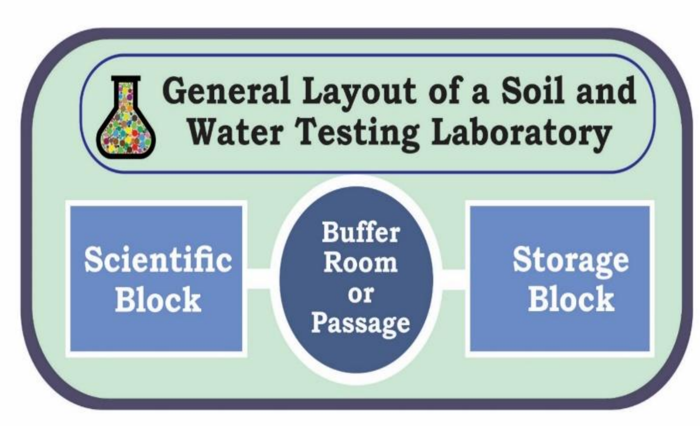


Fig. 4.4: General layout of a soil and water testing laboratory

Besides, there should not be direct connection between scientific and storage block, which helps to avoid contamination by dust while analyzing the samples (Fig. 4.4).

a. The scientific block

This block is primarily used for all the analytical determination including physical, chemical and biological properties of soil and water. This block also houses important equipment for soil and water analysis. It also comprises of different compartments or rooms for different analytical activities as shown in figure 4.5

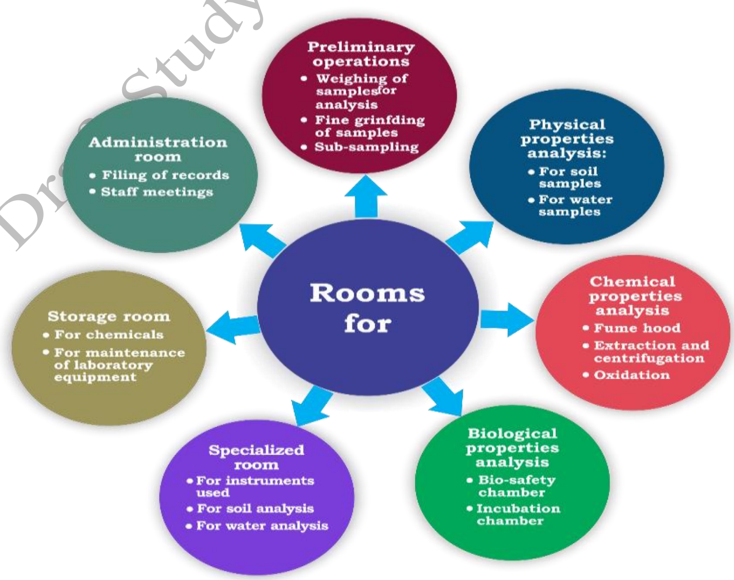


Fig. 4.5: Different rooms present in a scientific block

b. The storage block

The storage block consists of at least three rooms based on different operations

1. **Room for storage:** This room is used for the storage of samples, both before and after analysis, with adequate shelf space.
2. **Room for receipt**: In this room, all samples are given a receipt. The registration of all received samples is done with sufficient bench and shelf space.
3. **Room for processing:** In this room, soil samples are subjected to drying, crushing, grinding, milling and sieving. etc.

The different functions performed in the storage block are described in the figure 4.6.

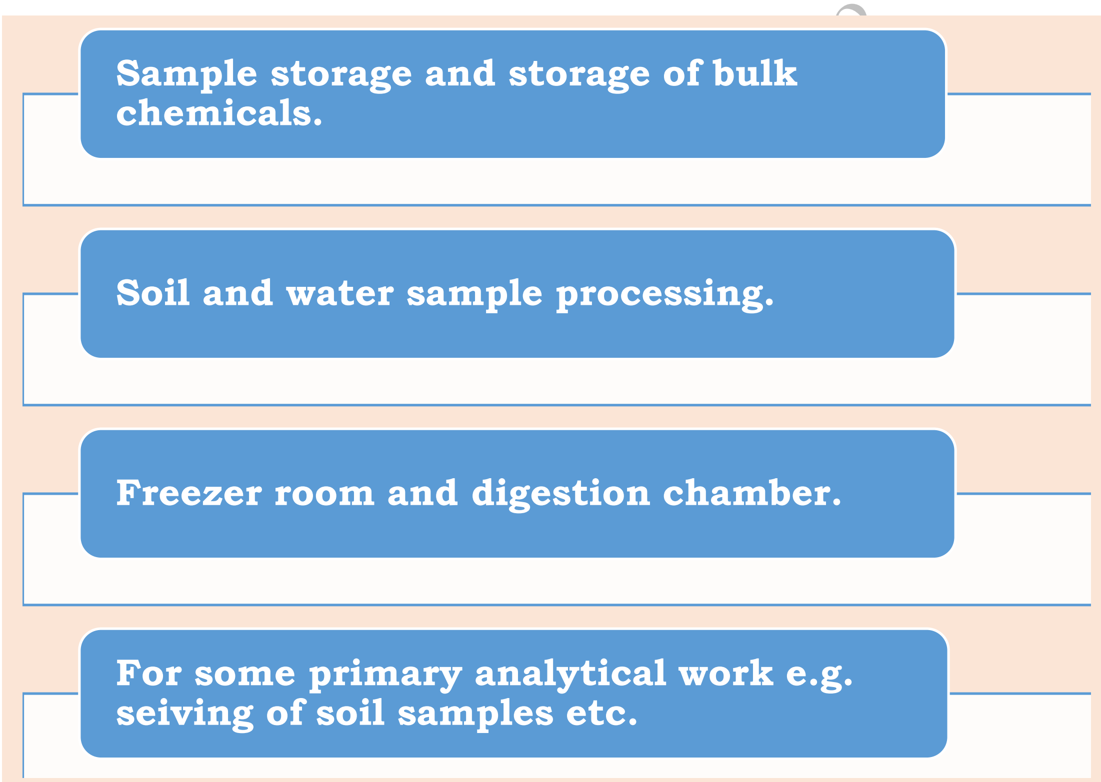


Fig. 4.6: Different functions of storage block

1.3 Proficiency testing

Proficiency testing refers to the determination of the performance of individual laboratories for specific tests in terms of quality and reproducibility of the results by an external agency. The FAO has given the basic guidelines for soil sample preparation for the proficiency testing which are described in the figure 4.7

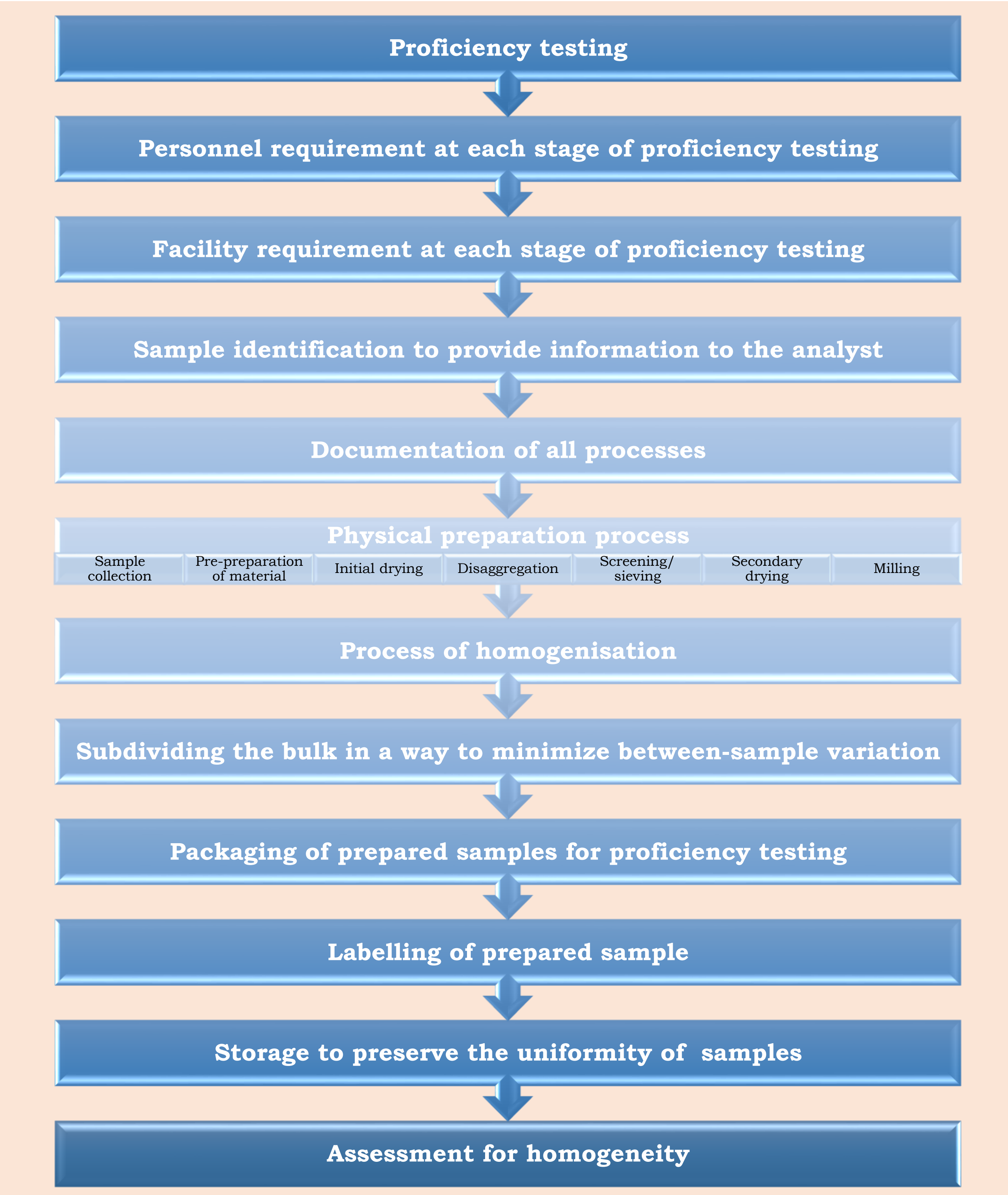


Fig. 4.7: Guidelines for soil sample preparation for the proficiency testing

1.4 Storage of soil and water samples

It is not always possible to analyze the received soil and water samples immediately. Therefore, proper storage of soil and water samples is essential before their analysis. The samples are stored in cool and dry place with proper labeling containing its ID and data sheet. The data sheet has information about location of the field, name of farmer, information regarding the slope of the field, its drainage, previous cropping history, and quantities of fertilizer and manures applied etc.

1.4.1 Storage of soil samples

The collected and already labeled soil samples are transferred to clean cloth or polythene bags. The labeling is done with thick paper tagged with sampling bags and also marked with permanent marker for double confirmation of sample ID.

The following points are to be taken care of while storing soil samples:

1. Collected samples are kept in sample storage room to avoid contamination and protect from direct sunlight.
2. Soil samples are kept at 4 °C for soil microbiological analysis.
3. Fresh samples need to be taken for soil chemical analysis in case of ammonical-nitrogen and nitrate-nitrogen content of soil samples.

1.4.2 Storage of water samples

- The water samples are collected in a clean glass or plastic container.
- The collected water samples are kept tightly capped in a container (Figure 4.8) after labeling. Sample ID is marked using location, sample identification mark on the bottle.
- In case of delay in testing of collected water samples, add 2-3 drops of toluene to prevent microbial growth.

Fig.4.8: Water sample bottles

1.5 Quality control

Quality control (QC) is one of the most important process on in lab analysis. It ensures both precision and accuracy of any sample analysis and its results. When quality control works effectively, we are able to find and correct flaws in the analytical processes. Thus, it helps in correcting the results of any analysis before the results are shared to the stake holders.

It remains the responsibility of the laboratory to ensure that proper quality is maintained in analysis of samples. There are three ways to achieve good quality data in lab analysis. They are:

1) Adhere to quality assurance guidelines scrupulously.
2) Participate in inter laboratory studies for cross checking analysis.
3) Use of certified reference materials.

1.6 Disposal of waste

In a soil and water testing laboratory, several types of wastes are generated such as broken glassware, expired and used up chemicals, denatured and carcinogenic chemicals, polluted and microbially infected soil and water samples etc. Therefore, the proper disposal of waste is one of the most important aspects in the safety considerations in a laboratory, which is carried out by taking utmost care and following all the safety guidelines and regulations. Some of the common steps that are carefully followed in a soil and water testing laboratory are enlisted below (Table 4.1)

Table 4.1: Safety Guidelines Followed in a Soil and Water Testing Laboratory

1.	Proper record of all the incoming and outgoing chemicals should be maintained.
2.	The harsh chemicals like strong acids and bases used in soil and water testing should be diluted before disposing them off.
3.	The toxic compounds like cyanides, persistent mineral oils, heavy metals like chromates, vanadates, molybdates etc. Salts of hazardous elements such as arsenic, lead, cadmium and mercury are never to be disposed via the sink. All such materials are collected properly in containers and disposed off in a prescribed manner.
4.	An inventory of toxic chemicals used in the laboratory is maintained so that a protocol for their collection and disposal is put in place.
5.	Waste sample remains are never disposed of by washing down a drain. Proper receptacles are used for this purpose.
6.	All the sinks and gullies are fitted with removable silt traps which are emptied regularly.

7.	Heavily polluted soil samples are treated as toxic chemical wastes.

1.7 Container types for handling laboratory waste

Different types of bins are used in the soil and water testing laboratory depending upon the kind of waste material. Fig. 4.9 (a-i) depicts the different kinds of laboratory wastes and the types of bins used for their disposal.

S. No.	Bin type	Type of waste	Symbols
1.	**Red bin** Biohazard laboratory waste	Tips, tubes, gloves, serological pipettes, Plastic Petri-dish etc.	a 
2.	**Blue bin** Broken glassware	Disinfected broken glass ware, glass container, pipettes etc.	b 
3.	**Halogenated solvent waste** White Canister, 5 litres	Chloroform, Dichloromethane, Carbon tetrachloride, Tetra-chloro-ethyelene, Per-chloroetylene etc.	c 
4.	**Non Halogenated solvent waste** White Canister, 5 litres	Acetone, Acetonitrile, Diethylether, Ethanol, Hexane, Methanol, Toluene, Dimethylsulfoxide, etc.	d 

5.	**White square container**	Sharps, Coverslips, Blades, Slides etc.	e 
6.	**Paper recycler**	Waste papers.	f 
7.	**Green bin**	Books, Papers, Catalogues etc.	g 
8.	**Cyan bin** E-waste	Battery, CDs, Pen drives, Cartridges, Floppies etc.	h 
9.	**New bins for broken bottles and vials with media**	Broken vials with media in them.	i 

Fig. 4.9 (a-i): Types of laboratory wastes and the containers used for them

Activities

Activity 1: You have been given 3 different coloured bins, one is red, one is green and the third one is blue. Based on the lesson taught in the class, identify the type of bin and write its use.

Requirements: Differently coloured bins, observation note-book, pen.

Step-by-step process: 1. Observe the provided coloured bins.

2. Make a note on each type and its use in your note-book.

3. Get it checked by your teacher.

Activity 2: You have been given the following laboratory materials:

1. Arsenic salts
2. Diluted acid solution
3. Microbially contaminated soil sample.

How would you safely dispose each one mentioned above? Discuss amongst your classmates and make a note of it.

Requirements: Given chemicals and soil samples, observation note-book, pen.

Step-by-step process:

1. Go to a soil and water testing laboratory with your teacher.
2. Observe the given chemicals (arsenic salts, diluted acid solution) and the soil sample (microbially contaminated soil sample).
3. Write the safe disposal methods for each of the samples provided.
4. Get it checked by your teacher and discuss amongst your classmates.

Check Your Progress

A. Multiple Choice Questions

1. Good laboratory practices (GLPs) include which of the followings
   a) Ensure representative sample collection
   b) Ensure the accuracy in analysis
   c) Generate high quality data
   d) Fulfill safety measures to be taken in the laboratory.
   e) All of the above

2. Which of the following is part of chemical analysis?
    a) Biosafety chamber
    b) Oxidation
    c) Physical separation of organic matter
    d) None of the above
3. Which of the following is the Preliminary operation in the scientific block in a soil testing laboratory?
    a) Preparation of reagent
    b) Filling of records
    c) Grinding of soil samples
    d) Analysis of soil and water
4. Which of the following is not part of 'FAIR' data management systems?
    a) Findable
    b) Reusable
    c) Accessible
    d) Suitable
5. Which of the following is a physical separation process in laboratory proficiency testing?
    a) Sample collection
    b) Initial drying
    c) Sieving
    d) Milling
    e) All of the above

B. Fill in the Blanks

1. Soil samples are kept at ……. degree Celsius for soil microbiological analysis
2. Collected water samples added with 2-3 drops of ……….to prevent microbial growth
3. ……….. is a halogenated solvent waste
4. ……… is done to remove root litters and other extraneous materials from the soil

5. …….. samples are collected in clean glass or plastic containers for analysis.

C. True or False

1. Waste sample remains in the laboratory are disposed of by washing down a drain.
2. Labelling of soil samples is done to avoid mixing with other samples
3. Proficiency testing does not refer to the determination of the performance of individual laboratories for specific tests in terms of quality and reproducibility of the results
4. For microbiological analysis samples are stored outside on laboratory bench
5. Heavily polluted soil samples are not treated as toxic chemical wastes.
6. In laboratory red bins are used for broken glasses or pipettes

Session 2: Occupational Health and Safety

Occupational health and safety (OHS) refer to the health, safety, and welfare at the workplace. It includes laws, standards, and programs to make the workplace better for workers, co-workers, family members, customers, and other stakeholders. The basic idea behind following OHS measures is to make the work environment safer and freer from accidents and injuries. So, identification of hazards at work place is important before we work in any laboratory.

2.1 Types of hazards in a soil and water testing laboratory

Hazard is any source of potential damage or anything that may cause injuries, harm or damages to the people or the equipment in a work place. A laboratory can be hazardous if not maintained and monitored carefully because many toxic chemicals are stored there. Such chemicals may cause injury or harm to the people who work there. Therefore, utmost care is taken in the laboratory. The major types of potential hazards in soil and water testing laboratory are depicted in figure 4.10

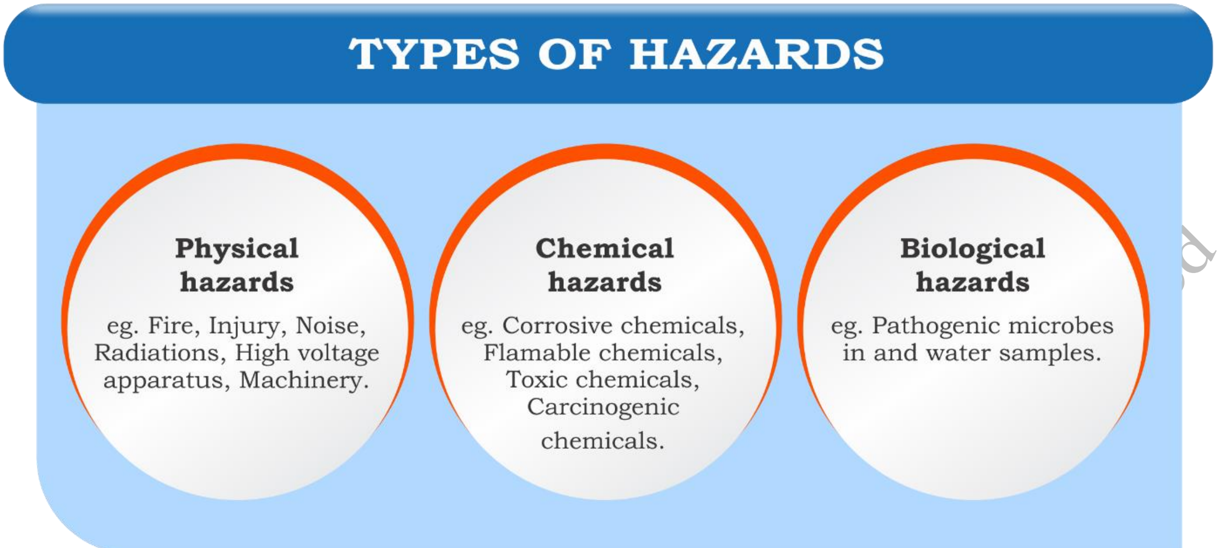
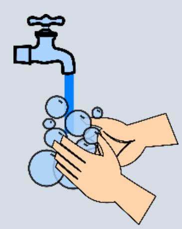
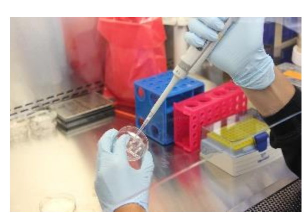


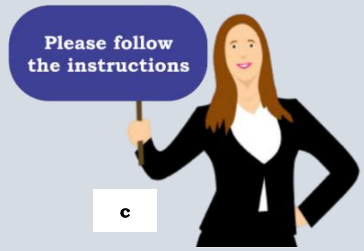
Fig. 4.10: Different types of hazards

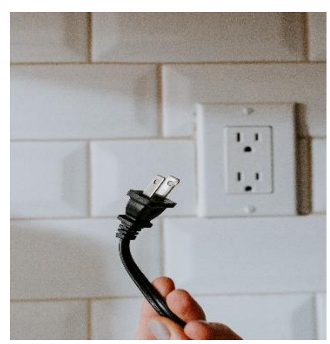
2.2 Hygiene and safety measures followed in a laboratory

Comprehensive measures need to be taken to achieve overall hygiene and avoid potential hazards in the laboratory. table 4. 2a (Fig. 4.11 a-m) give important hygiene and safety measures and table 4.2b give standard operating procedures (SOPs) followed in the lab.

Table 4.2a: Hygiene and Safety Measures Followed In A Soil and Water Testing Laboratory

Hygiene and safety measures		
1.	Always wash your hands properly with soap and water after handling chemicals. Tie back long hair when working in a lab.	a 
2.	Always wear gloves, apron, masks and safety goggles when working in a laboratory.	b 

3.	Read and follow the instructions of your teacher very carefully when working in a lab.	
4.	Notify the lab in-charge or your teacher of any accidental spill-overs.	
5.	Do not pour chemicals down the sink.	
6.	Keep your lab area clean. Never use broken, cracked or leaking glassware.	
7.	Use tongs or protective gloves to handle hot objects.	

8.	When heating a test tube, move it around slowly over the flame to distribute the flame evenly.	h 
9.	While lighting a burner, wait until the lighter is in place before you turn on the gas.	i 
10.	Lay electrical cords in a manner so that no one can trip over them or get caught in them.	j 
11.	Ensure that your hands and the laboratory surface are dry when using electrical equipment.	k 
12.	Unplug and switch off all the laboratory equipment at the end of the lab period.	l 

13.	Ensure fire extinguishers in all the biochemical labs are in working condition.	

Table 4.2b: Rules and SOPs Followed in a Soil and Water Testing Laboratory.

Rules and SOPs	
1.	All employees working in the laboratory must receive and understand the workplace hazardous materials information guide. The management or organization is responsible for proper instruction to the employees working in the laboratories.
2.	Running and jumping in the laboratory is strictly prohibited.
3.	Stored items or equipment shall not block access to the fire extinguisher, safety equipment, or other emergency items.
4.	No combustible material such as paper, wooden boxes, pallets, etc., shall be stored under stairwells or in hallways.
5.	Eating or drinking or smoking within laboratories is not permitted. No food or beverage should be stored in the laboratory refrigerators and freezers.
6.	Mouth pipetting of acids or alkalis are never allowed. Avoid working alone. If you work alone, have someone contact you periodically.
7.	Working hours of any institution are strictly followed. No worker shall work alone in a laboratory or chemical storage area outside the working hours. Permission for students and staff to work outside of the working hours has to be granted by the head of lab in-charge in writing.
8.	Learn emergency first aid. Seek medical attention immediately if affected by chemicals and use first aid until medical aid is available.

9.	Access to emergency exits, eye-wash fountains and safety showers must not be blocked.
10.	Do not use laboratory glassware for eating or drinking.
11.	Unauthorized persons should be kept out of a laboratory. Visitors should always be accompanied by authorized personnel.
12.	Do not use laboratory glassware for eating or drinking.
13.	Clothing worn in the laboratory should offer protection from splashes and spills, and should be easily removable in case of an accident.
14.	Routinely check for radiation leaks while working on X-ray or radiation equipment.
15.	Use fume hoods when handling concentrated acids, bases, and other hazardous chemicals.

2.3 First aid

Every person working in the laboratory should have knowledge of emergency first aid. In case of emergency necessary help needs to be given by others. Following measures are kept in mind to provide basic help in case of emergencies. Stay calm, try to understand the situation and to find out what is wrong with the casualty.

1. If the casualty becomes unconscious, turn the casualty on his/her side with the face tilted to the floor (support head by some kind of cushion).
2. In case of serious bleeding, arterial bleeding may be stopped by pressing a thumb in the wound.
3. Do not move the casualty unless he/she is in a dangerous position e.g., in case of gas, smoke, fire or electricity. Afterwards, carefully move the casualty to a safe and a well-ventilated place.
4. Call qualified help of medical service, a physician and/or an ambulance, and if necessary, the police as soon as possible. Do not leave the casualty unattended.
5. Take care that the casualty and keep breathing. If breathing stops, try to apply artificial respiration by mouth-to-mouth resuscitation. Table 3 depicts the first aid measures for common injuries in case of accidents taking place in a soil and water testing laboratory.

6. Make sure that in case of burns/burn emergencies in a soil and water testing laboratory the shower pulls (Fig 4.12a) and eye wash (Fig 4.12b) facility is used immediately.

Table 4.3: Common Injuries and the Corresponding First aid to be Given.

Common injuries		**First aid to be given**
1.	Burns	Dip affected parts of the skin for at least 10 minutes in cold water.
2.	Corrosive burns (e.g., burns by hydrogen peroxide)	Wash the affected part of the skin thoroughly with water. If eye burns, wash the eyes thoroughly with tap water, use an eye fountain or eye-wash bottle.
3.	Hydrofluoric acid burns	Wash the affected part with dilute ammonia (1-2%) solution or sodium bicarbonate solution.
4.	**Poisoning by swallowing**	
	a. Corrosive solutions (acids, bases)	Let the casualty drink one or two glasses of water to dilute the poison. Vomiting should not be induced.
	b. Petroleum product	Do not induce vomiting as the products may get into the bronchial tubes.
	c. Non-corrosive solutions (e.g., herbicides, fungicides)	Try to induce vomiting by making the casualty swallow activated charcoal.

Fig. 4.12a: Shower pull for emergency

Fig. 4.12b: Eye-wash facility in laboratory

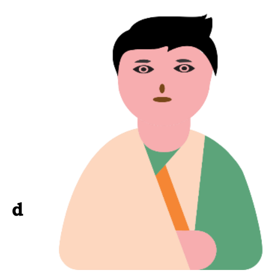
a *b*

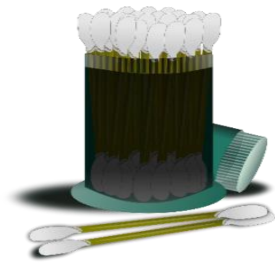
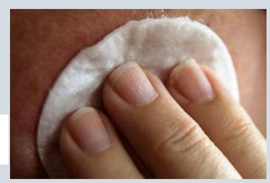
2.3.1 First aid kit

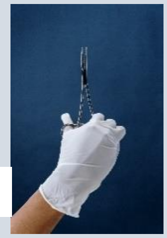
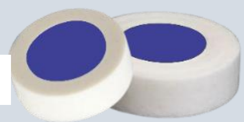
It is a small box containing items such as bandages, plasters, and antiseptic wipes etc. (Table 4, Fig 4.14 a-t) for use in giving help to a sick or injured person until full medical treatment is available. A typical first aid box used in the soil and water testing laboratory is shown in figure 4.13.

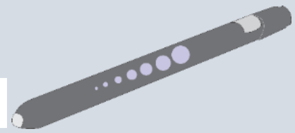
Fig. 4.13: First aid box

Table 4.4: Contents of the First Aid Kit

CONTENTS		
1.	Antiseptic solution (1ml)	
2.	Conforming Bandage (100mm)	
3.	Crepe bandage (50mm)	
4.	Triangular bandage	

5.	Burn dressing 10cm x10cm	e 
6.	Cotton buds	 f
7.	1x Cotton wool pad 12.5 g	g 
8.	1x CPR mouthpiece	h 
9.	1x First aid dressing no. 3	i 
10.	1x First aid dressing no. 5	j 

11.	1x Stainless steel forceps	k 
12.	1x Pair medium latex gloves	l 
13.	1x Paper tape (non-allergenic)	m 
14.	10x Plaster strip	n 
15.	10x Safety pins	 o
16.	1x Budget scissors	p 
17.	1x Rescue blanket	q 

18.	1x Plastic splints	r 
19.	1x Pupil torch	s 
20.	1x Digital thermometer	t 

2.5 Storage and labeling of chemicals in a lab

Proper storage of various chemicals is essential for safety of the worker and provides security and a "user friendly" system for end user of the chemicals.

a. All containers used for storage of chemicals are properly labelled.

b. Quantities greater than one litre of highly flammable liquids (e.g., Methanol, Ethanol and Chloroform) are stored in specified metal cabinets with stickers.

c. Chemicals are stored as close to the point of use as possible to maximize efficiency and minimize transport distance.

d. Periodical update of the stock of chemicals is carried out to dispose off the out-of-date chemicals to reduce potential hazard.

2.5.1 Storage of hazardous chemicals

All hazardous chemicals have chemical safety data sheets (CSDS) which contain information such as its chemical composition, category of its hazard, precautions in handling, first aid and firefighting measures, date of manufacture and its expiry and manufacturer information. The instructions on the CSDS are strictly followed. In addition, the following measures and precautions are taken while storing hazardous chemicals.

- Unauthorized access of such chemicals is prohibited
- Keep minimum amounts of such chemicals on site.

- All chemicals are properly labeled with relevant warning symbols.
- Avoid exposing such chemicals to the direct sun light or heat.
- With adequate ventilation, keep the storage area clean and tidy
- Don't store incompatible chemicals together e.g. oxidizing and reducing agents are not stored together. Acids are not stored with organic liquids.
- Ensure that the shelves are not overloaded with such chemicals.

Table 4.5 presents a list of different types of hazardous chemicals, their examples, their representative symbol and preventive actions taken in case of emergencies caused due to them.

Table 4.5: Different Types of Hazardous Chemicals

Type of chemical materials	Hazard symbol	Caution	Preventive action	Examples
Explosive		This symbol indicates substances which can explode.	Avoid shock, friction, sparks and heat.	Acetone, Ammonium nitrate, Tri-nitro-toluene (TNT), Urea perchlorate, Ammonium permanganate etc.
Oxidizing agent		This symbol indicates oxidizing substances which can ignite as they are combustible materials or worsen existing fires and thus, make fire-	Keep such chemicals away from combustible materials.	Hydrogen peroxide (H_2O_2), Nitric acid (HNO_3), Sulphuric acid (H_2SO_4), Potassium nitrate (KNO_3) etc.

		fighting more difficult.		
Highly inflammable		This symbol indicates spontaneously flammable substances if comes in contact with air.	Avoid contact with air.	Benzene, ethanol, etc.
		1) Highly flammable gases.	Avoid formation of flammable gas-air mixtures and keep away from sources of ignition.	Acetylene, Ammonia, Methane etc.
		2) Substances sensitive to moisture and chemicals which readily form flammable gases on contact with water.	Avoid contact with moisture or water.	Benzene, Ethanol, Methanol, acetone etc.
		3) Flammable liquid i.e., liquid with a flash point below 21^0C.	Keep away from open fires, sources of heat and sparks.	Ethanol, acetone etc.

Highly toxic		This symbol indicates substances which are very hazardous to health when breathed, swallowed or comes in contact with the skin, may even lead to death.	Avoid contact with the human body and immediately consult a doctor in case of such incidents.	Chloroform, formaldehyde, methanol, mercuric chloride, sodium hydroxide etc.
Harmful		This symbol indicates substances which when taken up by the body can cause slight damage.	Avoid contact with the human body including inhalation of the vapors and in case of accident, consult a doctor.	Chloroform, methanol, sodium hydroxide etc.
Corrosive		This symbol indicates chemicals which can damage living tissues as well as equipment.	Don't breathe vapors and avoid contact with skin, eyes and clothing.	Sodium hydroxide, sulphuric acid, hydrogen peroxide, bromine etc.

Irritating		This symbol indicates substances which may have an irritant effect on skin, eyes and respiratory organs.	Don't breathe vapors and avoid contact with skin and eyes.	Chloroform, formaldehyde, methanol, sodium hypochlorite, sodium hydroxide.
Hot surface		This symbol indicates extreme temperatures which are potential lab hazard.	Some of the hot plates can reach temperatures of 450 °C, so when you are using them, be careful.	Hot plates, digestion blocks etc.
Cold hazard		This symbol indicates extreme low temperatures which are a potential lab hazard.	Workers must wear appropriate warm clothing under a lab coat. No dry ice, liquid nitrogen, compressed gas, flammable liquids, volatile chemicals should be carried	Dry ice, liquid nitrogen, compressed gases etc.

			inside the cold room.	
Biohazard		This symbol indicates hazardous biological agents.	Disinfect gloves and hands. Washing your hands frequently with warm water and soap. Wearing personal protective equipment (PPE) when responding to situations involving bio hazards. Avoiding direct contact with the biohazardous agents. Use the right bins to dispose off such substances.	Bacteria, virus, fungus etc.

Electrical hazard		This symbol indicates an electrical hazard that is a dangerous condition where a worker can come in contact with charged equipment or a conductor.	Inspect wiring of equipment before each use. Know the location of the switches and how to operate them along with their circuit breaker panels.	pH meter, EC meter, Flame photometer, Spectrometer, Atomic absorption spectrometer etc.
Radiation hazard		This symbol indicates potential radiological hazards.	Death may occur in days or weeks and increase risk of cancer in later part of life.	Neutron moisture meter for soil moisture estimation, Depth density probe/gauge.

2.6 Emergency response in case of fire

On seeing fire, alert others. Break glass of fire alarm switch and press alarm. The security officer should be immediately informed about fire. Don't panic and stay calm. In case of massive fire outbreak call the fire brigade immediately. Figure 4.15 shows the different kinds of fire extinguisher and their applicability.

Extinguisher		Type of Fire				
Colour	**Type**	**Solids (wood, paper, cloth etc.)**	**Flammable liquids**	**Flammable gasses**	**Electrical** equipment	**Cooking oils & fats**
	**WATER**	YES	NO	NO	NO	NO
	**FOAM**	YES	YES	NO	NO	YES
	**DRY POWDER**	YES	YES	YES	YES	NO
	CORBON DIOXIDE (CO_2)	NO	YES	NO	YES	YES

Fig. 4.15: Different kinds of fire extinguisher and their applicability

For the fires that can be managed, use appropriate fire extinguishers as explained below:

2.6.1 Using a fire extinguisher

- If you are attempting to put out a fire then you need to know the location of fire extinguishers and its operational procedure.
- Try **attempting to put out a fire if there is a clear exit from the room**.
- Never turn your back on a fire.
- Most of the extinguishers will work for approximately 30 second. If you are unable to stop the fire in that time, then vacate the area immediately.
- Once you leave a burning room, do not re-enter it.
- Do not lock the door of the burning room and leave it unlocked as the fire department will need to enter.
- If you know the cause and type of fire and the different chemicals stored in room, immediately inform the fire fighters.

2.6.2 Laboratory requirements for fire-fighting

A laboratory must be minimally equipped with the following kits:

1) Fire-proof blankets.
2) Buckets with sand.
3) Commonly used portable fire extinguishers of two types: Air pressurized CO_2 or halogenated hydrocarbons since these can be used without causing damage to electrical equipment.

2.6.3 Actions taken in case of a fire

In case of a fire, following actions are taken in the order given below:

1) Close windows and doors.
2) Raise an alarm (shouting, telephone, fire alarm).
3) Rescue people and animals.
4) Switch off electricity and gas supply.
5) Persons with burning clothing should be wrapped immediately with a blanket and made to lie down on the floor. A CO_2 fire extinguisher can also be used, but do not spray in the face.
6) The fire is extinguished at the seat of the fire and not in the middle of the flames.

7) If gas cylinders are present there is the danger of explosion by overheating. If they cannot be removed, take cover and try to cool them with a fire-hose.

8) When the situation looks out of control, evacuate the building. Let everybody assemble outside.

9) A regular fire drill should be held. (This must be included as an activity by the students)

Check Your Progress

A. Multiple Choice Questions

1. Which of the following hazard is not visible to naked eye?
   a) Fire hazards
   b) Various chemical hazards
   c) Pathogenic hazards
   d) Machinery hazards
2. Which of the followings hygienic and safety measures are taken in the laboratory?
   a) Washing hands always before entering the lab
   b) Wearing gloves, apron and safety
   c) Reading and following the instructions
   d) Notifying the lab in-charge in case of any accident
   e) All of the above
3. Which type of fire extinguisher can be used in case of fire from electrical items
   a) Water
   b) Foam
   c) Dry powder
   d) Ice
   e) None of the above
4. Preventive actions for highly inflammable hazardous materials are
   a) Avoid eye contact
   b) Keep away from open fire

c) Keep away from source of Ignition

d) All of the above

e) None of the above

5. The example of irritant chemical hazards is

a) Hydrogen peroxide

b) Liquid nitrogen

c) Potassium nitrate

d) None of the above

B. Fill in the Blanks

1. …….. is small box containing items such as bandage, plasters and antiseptic cream etc.
2. …………is an example of corrosive materials for chemical hazards.
3. ……. is used in the laboratory to handle hot objects.
4. In case of hydrofluric acid burn, ……. is used as remedial measure.
5. ………. is a halogenated solvent waste.

C. True or False

1. In laboratory analysis, it is a visible to add water into the acid.
2. Heavily polluted soil samples are not treated as toxic chemical wastes.
3. Personal protective equipment (PPE) is an effective option in case of bio-hazrads
4. Mouth pipetting of acids or alkalis are allowed in the laboratory
5. Wearing gloves, apron, masks and safety goggles is must while working in a laboratory.

Answer Keys

Module 1

Session 1

A: Multiple Choice Questions

1	c	2	d	3	b	4	d	5	b

B: Fill in the Blanks

1 Soil weathering 2 Horizons 3 Carbonation

4 Hydration 5 Oxidation and reduction

C: True or False

1 True 2 False 3 True 4 False 5 False

Session 2

A. Multiple Choice Questions

1	b	2	d	3	d	4	c	5	D

B. Fill in the Blanks

1 Feel Method 2 Soil Structure 3 Peds

4 Soil Texture 5 Bulk density

C. True or False

1 False 2 False 3 False 4 False

5 False 6 True

Session 3

A. Multiple Choice Questions

1	c	2	A	3	b	4	b	5	c

B. Fill in the Blanks

1 Calcium, potassium and sodium 2 Available nutrients

3 6.5-7.5 4 pH meter 5 Conductivity meter

C. True or False

1 True 2 False 3 True 4 True 5 False

Session 4

A. Multiple Choice Questions

1 a 2 B 3 a 4 a 5 a

B. Fill in the blanks

1 Vermicompost 2 Decaying organic materials 3 Root exudates 4 Eisenia foetida 5 Hyphae

A. True or Flase

1 False 2 False 3 True 4 True 5 False

Session 5

A. Multiple Choice Questions

1 e 2 d 3 a 4 D 5 d

B. Fill in the Blanks

1 Black soils 2 90-95% 3 Nitrogen and organic matter

4 Laterite 5 Histosols

A. True or False

1 False 2 True 3 False 4 True 5 True

Module 2

Session 1

A.Multiple Choice Questions

1 b 2 d 3 d 4 a 5 a

B. Fill in the Blanks

1 17 2 100 3 Diffusion 4 High 5 Mass flow

C. True or False

1 True 2 False 3 False 4 True 5 False

Session 2

A. Multiple Choice Questions

1 c 2 c 3 b 4 c 5 d

B. Fill in the blanks

1 0.5% 2 Primary nutrient fertilizer 3 Straight fertilizer

4 Complex 5 60%

C: True or False

1 False 2 False 3 True 4 False 5 True

Session 3

A. Multiple Choice Questions

1 a 2 a 3 b 4 D 5 a

B. Fill in the blanks

1 Soil fertility 2 Small 3 Plant and Animal

4 Plant growth 5 Zea mays

C. True or False

1 True 2 True 3 True 4 False 5 False

Module 3

Session 1

A. Multiple Choice Questions

1 c 2 d 3 d 4 b 5 C

B. Fill in the blanks

1 1955-56 2 Toluene 3 N and S

4 Alkaline 5 Residual Sodium Carbonate

C. True or False

1 True 2 True 3 False 4 False 5 False

Session 2

A. Multiple Choice Questions

1 a 2 d 3 A 4 c 5 d

B. Fill in the Blanks

1 250C 2 Lithium 3 calibration curve 4 Excited state

5 Toxic or hazardous

C. True or False

1 False 2 False 3 True 4 True 5 True

Session 3

A. Multiple Choice Questions

1 d 2 d 3 b 4 d 5 a

B. Fill in the Blanks

1 < 2 dS m-1 2 >0.75 % 3 >280 kg/ha 4 <0.7ppm

5 arid, semiarid

C. True or False

1 False 2 True 3 True 4 True 5 True

Module 4

Session 1

A. Multiple Choice Questions

1 e 2 b 3 b 4 d 5 e

B. Fill in the blanks

1 4 ° C 2 Toluene 3 Chloroform 4 Sieving 5 Water

C. True or False

1 False 2 True 3 False 4 False 5 False 6 False

Session 2

A. Multiple Choice Questions

1 E (wrong as no option of e) 2 b (e) is the correct answer

3 c 4 d 5 a

B. Fill in the Blanks

1 First aid kit 2 Sodium hydroxide 3 Tongs/protective gloves4.

4 Sodium bicarbonate 5 Chloroform

C. True or False

1 False 2 False 3 True 4 False 5 True

Glossary

Acid Soils: Soil having the pH < 6.5. These soils are generally rich in aluminum and iron oxides and found in areas with high rainfall and high altitude, where most of the basic cations (Ca, Mg) are washed away and makes the soil acid

Available Nutrients: Any nutrient in the soil solution that can be absorbed readily by plant roots is called available nutrients. The available amount of nutrient is usually much less than the total nutrient present in the soil.

Available Nutrients: Nutrients present in the soluble form are readily. available to the plants. Such nutrients are known as available nutrients.

Bulk Density: It is the weight of soil solids per Module volume of total soil.

Chemical safety data sheets (CSDS): It contains all hazardous chemicals information's such as its chemical composition, category of its hazard, precautions in handling, first aid and firefighting measures, date of manufacture and its expiry and manufacturer information.

Clods: Soil aggregates formed due to agricultural practices like tillage and intercultural operations

Complex fertilizers: These fertilizer products, which supplies more than one primary nutrient, is called complex fertilizers.

Composting: It is an aerobic method of decomposing organic matter or wastes. In the process, organic material gets converted into a humus-like material known as composting. It is a good source of plant nutrients.

Diffusion: It is the movement of nutrients to the root surface in response to a concentration gradient. When nutrients are found in higher concentrations in one area than another, there is a net movement to the low-concentration area to reach equilibrium. It is important for the transport of phosphorus and potassium.

Electrical Conductivity: It measures the salt contents of a liquid or soil samples. In other words, the amount of salts present in the soil is measured as electrical conductivity.

Essential nutrients: Any mineral element that follows the "criteria of essentiality" There are 17 essential elements identified for plant growth.

Farm yard manure (FYM): The FYM is decomposed mixture of dung and urine of farm animals and litter used as bedding material and residues from the fodder fed to the cattle. It is the most common organic manure applied in the agricultural field.

Fertilisers: Fertilisers are the organic or inorganic chemical synthetic compounds that supply nutrient to crop to increase the crop yield. For example, Urea is the organic synthetic compound, whereas, ammonium sulphate is the inorganic synthetic compound.

Field Capacity: After the drainage of excess water, the larger soil pores are filled with air and water while the smaller pores are still full of water at this stage called field capacity.

Good laboratory practices: During soil and water testing, we need to follow standard procedures and techniques to get accurate results from soil and water samples analysis. These techniques are termed as "Good Laboratory Practices" (GLPs).

Green Manures: It is the practice of mixing undecomposed green plant into the soil. It improves the soil structure, soil organic carbon (SOC) and soil fertility. Some of the green manure plants are Dhaincha (*Sesbania Aculeate*), Sunn hemp (*Crotalaria Juncea*), and Glyricidia (*Glyricidia Maculeata*).

Hazard: It is any source of potential damage or anything that may cause injuries, harm or damages to the people or the equipment in a workplace

Horizon: Soil profile is differentiated into distinct layers. These layers known as horizons.

Humification: It is the process of conversion of organic material into humus

Hydration: It is the chemical combination of water with another substance. The hydrated substances show different physical and chemical properties.

Hydrolysis: Hydrolysis is the chemical breakdown of the minerals by reacting with water.

Integrated nutrient management system: It refers to plant nutrient supply at an optimum level for sustaining the crop productivity by applying nutrients from all possible sources in an integrated manner.

Macronutrients: Any of the elements required in large quantities by all living things. For example, nitrogen, phosphorous, potassium, calcium etc,

Manures: Manures are the decomposed plant and animal matters used as plant nutrients to increase crop production. Manure provides most of the plant nutrients but in the small quantities.

Mass Flow: The movement of dissolved nutrients (in water) into a plant as the plant absorbs water for transpiration. This process is responsible for transporting most nitrate, sulfate, calcium, and magnesium in the soil.

Micronutrients: Plant needs this element in a relatively smaller amount (≤100 mg/kg/dry weight). The essential elements, namely Fe, Mn, Zn, Cu, Mo, Cl, Ni, B, are known as micronutrients or trace elements or minor elements.

Mineralization: It is the process of release of mineral constituents from organic matter decomposition

Occupational health and safety (OHS): It refers to the health, safety, and welfare at the workplace

Organic farming: It is cultivation practice involves growing of plants and animals in natural ways. In this farming use of materials from biological sources, avoiding synthetic materials like fertilizers, hormones, pesticides and feed additives etc. to maintain soil fertility and animal health and protects the environment, thereby minimizing pollution.

Pedoturbation: It is a process of mixing soils by biological or physical means

Peds: Units of soil structure are called Peds *or* naturally occurring soil aggregates

Permanent Wilting Point: After the soil has reached its field capacity, the water content present in the soil is used up gradually by the process of evapotranspiration, the soil reaches to permanent wilting point. At this point, the plants start to wilt, and beyond which plant may die, this stage is called Permanent Wilting Point (PWP).

Pore space: Soil space is occupied by about 50 % solids (mineral and organic matter) and 50 % space. This space is called pore space.

Poultry manure: It is the by-product of poultry production. It includes waste poultry feed, solid and liquid poultry dropping, litter, eggshell, feathers and the wastes from poultry sheds. It is rich in nitrogen (N), phosphorus (P) and trace elements for crop production. It also improves physical, chemical and biological health of soil.

Primary nutrient fertilizer: This fertiliser provides primary nutrient such as nitrogen, phosphorous and potassium to plant is known as primary nutrient fertilizer.

Proficiency Testing: It refers to determining the performance of individual laboratories for specific tests in terms of quality and reproducibility of the results by an external agency.

Quality control (QC): It is one of the most important processes in lab analysis. It ensures both the precision and accuracy of any sample analysis and its results.

Quartering: It is usually done during soil sampling collection by dividing the bulk into four equal parts. The two opposite quarters are discarded and the remaining two quarters are remixed. The process is repeated until we get the desired amount of representative soil samples.

Rhizosphere: It is the area directly influenced by plant roots on relative population of soil microorganisms. It is also called as plant-root interface.

Root Interception: It occurs when the growth of a root comes into contact with soil colloids containing nutrients. The root then absorbs the nutrients. Plant absorbs calcium (Ca) and magnesium (Mg) through this process but is a minor pathway for nutrient transfer.

Saline Soils: Soil having the pH > 8.5. These soils contain a higher amount of neutral soluble salts which adversely affect the plant growth. It consists of chlorides (Cl^-) and sulphates (SO_4^{2-}) of sodium (Na), calcium (Ca), magnesium (Mg) and potassium(K).

Saturation: During prolonged rainfall or on well-irrigated fields, all the soil pores are filled with water. This condition is known as saturation or maximum water holding capacity.

Secondary nutrient fertilizer: It provides secondary nutrient such as calcium, magnesium, and sulphur to the plants.

Secondary Nutrients: Ca, Mg, and S are called "secondary" nutrients, because plants require them in smaller quantities than nitrogen, phosphorus, and potassium.

Sodic Soils: Soils containing sodium salts such as Na_2CO_3 termed as 'Alkali' in older literature.

Soil Biota: It is a collective term that comprises of all organisms present in the soil. Soil organisms include earthworms, nematodes, protozoa, fungi, bacteria, different arthropods as well as some species of burrowing reptiles and mammals.

Soil Fertility: It is the ability *of a* soil to supply essential plant nutrient for plant growth and agricultural production. The soil's nutrient supply capacity is improved by adding organic manures (e.g., farm yard manures and vermi-compost), compost, crop residues, and fertilizers.

Soil Genesis: The process of soil formation is known as soil genesis.

Soil health: It refers to the soil's capacity to perform the different functions, e.g., nutrient cycling, buffering, filtering, biodiversity and crop production etc.

Soil pH: It is a measure of the acidity or alkalinity of the soil. Sometimes it is called soil reaction. pH is a measure of the H+ ion concentration, and it measured on a scale of 0 to 14.

Soil Productivity: The crop producing capacity of a soil is measured in terms of economic output such as crop grain and biomass yield. It also provides favourable chemical, physical, and biological characteristics as a habitat for plant growth. Productive soil must contain all the 17 essential nutrients required by the plants.

Soil Separates: Soil primary particles are classified into sand, silt and clay are also known as soil separates.

Soil Structure: The arrangement of the individual soil primary particles (sand, silt, clay) into large units is called 'soil structure'.

Soil Testing: Soil test is performed to quantify the different soil health indicators. Testing of soil includes many parameters starting from soil pH to available nutrients (i.e., primary, secondary and micronutrients) using different methods and procedures. The basic idea behind soil testing is to recommend optimum fertilizer quantities for plant growth and crop production.

Soil Texture: The relative content of primary soil particles such as sand, silt and clay in the soil.

Soil: The term 'Soil' is derived from the *Latin* word "SOLUM" means floor. Soils serve as a natural medium for plants' growth.

Straight fertilizers: Some fertilizer products supply only one primary nutrient. For example, Urea provides only nitrogen, and superphosphate only supplies phosphorous to plants. These types of fertilizers are called straight fertilizers.

Total Nutrients: It is the total amount of nutrient present in the soil. The presence of total quantities of essential nutrients in a *soil* does not guarantee the availability of these nutrients in full amount to growing plants

Vermicomposting: It is the type of manure in which certain earthworm species transform the organic wastes into the nutrient-rich manure. *Eisenia foetida* are most efficient earthworm spacing in vermicomposting.

Water testing: It is a process in which we will know the quality of water and its uses i.e., drinking water for irrigation. The water analysis data is essential to judge the suitability of water

List of Credits

Module-1:

Fig. 1.22 (a-d): Dr. A. Mandal, Scientist, ICAR-IISS, Bhopal

Fig. 1.23 (a-b): Dr. A. Mandal, Scientist, ICAR-IISS, Bhopal

Fig. 1.24 (a-h): Dr. A. Mandal, Scientist, ICAR-IISS, Bhopal

Fig. 1.25 (a-c): Dr. A. Mandal, Scientist, ICAR-IISS, Bhopal

Fig. 1.29 (a-l): https://tinyurl.com/n8m8u48u and https://tinyurl.com/azkn94r7

Fig. 1.30 (a, b): Dr. N Kumar, Scientist, ICAR-NBSS & LUP

Fig. 1.31: https://tinyurl.com/9hrayvaw

Fig. 1.32: Maji et al., 2012

Module-2:

Fig. 2.4 (a, b): Marschner and Rengel, 2012.

Fig. 2.7 (a): Dr. Monoranjan Mohanty, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 2.7 (b): Dr. Asit Mandal, *Senior Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 2.7 (c): Dr. Nishant K Sinha, *Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 2.7 (d): Dr. Somasundaram Jayaraman, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Module-3:

Fig. 3.7: Dr. Asit Mandal, *Senior Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 3.10: Dr. Somasundaram Jayaraman, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 3.11: Dr. Monoranjan Mohanty, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 3.12: DAAH, PSSCIVE, Bhopal.

Fig. 3.13: Dr. Mukur Ganguly, Research Scholar, TFRI, Jabalpur.

Fig. 3.14: Dr. Nishant K Sinha, *Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 3.15: Dr. Somasundaram Jayaraman, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 3.17 a: Dr. Somasundaram Jayaraman, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Module-4:

Fig. 4.3: Dr. Monoranjan Mohanty, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 4.7: https://tinyurl.com/y4g2wv2y

Fig. 4.8: Dr. Nishant K Sinha, *Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 4.9 (a-i): Dr. Monoranjan Mohanty, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 4.11 (a, b, c, k): www.pixabay.com

Fig. 4.11 (l): www.unsplash.com

Fig. 4.11 (d, e, f, g, i, m): Dr. Monoranjan Mohanty, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 4.11 (h, j): DAAH, PSSCIVE, Bhopal.

Fig. 4.12 (a, b): Dr. Somasundaram Jayaraman, *Principal Scientist*, ICAR-Indian Institute of Soil Science, Bhopal.

Fig. 4.13: DAAH, PSSCIVE, Bhopal.

Fig. 4.14 (a, b, c, f, g, k, l, o, p, t): www.pixabay.com

Fig. 4.14 (d, e, h, j, m, n, q, s): DAAH, PSSCIVE, Bhopal.

Fig. 4.14 (i, r): www.unsplash.com

Fig. 4.15: DAAH, PSSCIVE, Bhopal.