SOIL SCIENCE

(Training Material)

DIRECTORATE OF FORESTS
GOVERNMENT OF WEST BENGAL

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PREFACE

Soil forms the foundation of forests. It has a critical role in the cycling of nutrients, which influences the growth of individual trees and functioning of the forest ecosystem. It is therefore necessary that forest managers learn the fundamentals of soil science to understand how soil regulates the availability of resources to the plants. As part of the JICA project on 'Capacity Development for Forest Management and Training of Personnel' being implemented by the Forest Department, Govt of West Bengal, this course material on Soil Science has been prepared for induction training of the Foresters and Forest Guards. The object of this training manual is to present the basic aspects of soil science.

The subjects covered in this material broadly conform to syllabus laid down in the guidelines issued by the Ministry of Environment of Forests, Govt of India, vide the Ministry's No 3 -17/1999-RT dated 05.03.13. In dealing with some of the parts of the course though, the syllabus has undergone minor revision. Some topics have been deleted and some topics have been included to facilitate complete understanding of the subjects and to provide their appropriate coverage. The revised syllabus, with such modifications, is appended.

As this material is meant for the training of frontline staff of the Department, effort has been made to present the subject in simple and easy language and to avoid complex scientific theories and calculations.

The contents of the course material have been compiled and edited by A Basu Ray Chaudhuri, IFS (Retd), while working for and on behalf of project consultant Indian Institute of Bio-Social Research & Development (IBRAD). Many books, documents and information have been made use of in preparing the course material and references to such books, documents, etc. have been cited in the respective lessons. Thanks are due to many forest officers who have helped in the preparation of this material.

Efforts that have gone into making of this course material will be best rewarded if the frontline staff of the forest department find it useful in their day-to-day work.

Kolkata, 2016

(N K Pandey, IFS)
Principal Chief Conservator of Forests (General), West Bengal
&
Chairman, State Project Management Unit

SOIL SCIENCE SYLLABUS

Soil Science (5 hours), Excursion 1 day		
1. Rocks and Soil	1-1. Rocks • Igneous • Sedimentary • Metamorphic 1-2. Soil formation • Physical weathering • Chemical weathering • Biological weathering 1-3. Soil profile and horizons 1-4. Physical properties – Soil texture, structure, porosity*, soil water and plant relations*, Chemical properties – macro-micro nutrients*, cation exchange capacity*, soil pH, soil organic matter*, humus* Biological properties - soil flora*, soil fauna*, soil micro-organisms, biological activity*	3* hours
2. Soil types	2-1. Important soil types and their properties • Alluvial soils • Black soils • Red soils • Lateritic soils • Desert soils • Saline soils • Alkaline soils • Acid soils • Peaty and marshy soil* 2-2 Soils in West Bengal* • Agro-Ecological Classification of soils in West Bengal* • Soil problems in West Bengal*	1* hour
3. Nutrients and Soil testing*	3.1. Functions of major plant nutrients* 3.2. Soil nutrients as index of fertility* 3.3. Soil testing methods.*	1* hour
Field Study	Study of soil profile	

* These are modifications to the MoEF-prescribed syllabus, indicating addition/ revision of topics and change in lesson hours.

Contents

Lesson-1

SOIL SCIENCE

Time 1 hour

Lesson Plan

Objective:

- To understand function of soil in a forest ecosystem.
- To know about parent materials of soil.
- To study soil formation process – weathering
- To know about soil profile and horizons.

Forward Linkage:

- During tour the trainees may be shown profiles of forest soil in different agro-climatic zones.

Training materials required:

- Copy of lesson 1 to be circulated beforehand.
- Demonstration of various types of rocks.

Allocation of time:

- Function of soil – 5 min
- Study of rocks and demonstration – 25 min
- Soil formation – weathering – 10 min
- Soil profile and horizons – 10 min
- Discussion/miscellaneous – 10 min

1. Soil – foundation of forest eco-system

Soil provides the following three basic resources for survival and growth of the trees.

- Water
- Mineral nutrients
- A porous medium for physical anchorage

Soil also plays a critical role in the process of cycling of nutrients and thereby influences the growth of forest crop. Thus soil forms the foundation of forest ecosystems.

1.1 Soil is the top layer of the earth's surface consisting of rocks, minerals, organic matter, water and gases. It forms a porous medium in which plants can grow.

2. Soil - parent material

The geologic material to which a typical soil owes its origin is called its parent material. The parent material is broadly classified into two categories –

- **Consolidated** - Igneous, sedimentary and metamorphic rocks belong to this category.
- **Unconsolidated** – This category includes mineral particles which had been moved from their respective points of origin. Various transporting agencies like snow, water, wind, gravity, etc. cause such movement

3. Rocks

Depending on their mode of origin rocks are classified as –

- igneous,
- sedimentary, and
- metamorphic.

3.1 Igneous rocks solidify from magma or molten material either within the earth's crust or extrude on the surface as volcanic material. Based on their depth of occurrence they are further classified into three types (Introductory Soil Science – by S.S Negi)

(1) Plutonic – formed deep inside the bowels of earth
(2) Hypabassal – formed at intermediate zone;
(3) Volcanic – formed at the surface

Some igneous rocks are: Granite, Granodiorite, Syenite, Pitchstone, Basalt, Gabbro, Dolerite, Pegmatite, Peridotite etc.

3.2 Sedimentary rocks are formed from the deposition of fragments of pre-existing rocks, from the accumulation of shells or other organic material, or from the precipitation of chemical compounds.

3.2.1 The sedimentary rock cover of the continents of the Earth's crust is extensive, but the total contribution of sedimentary rocks is estimated to be only 8% of the total volume of the crust. Sedimentary rocks are only a thin veneer over a crust consisting mainly of igneous and metamorphic rocks. Sedimentary rocks are deposited in layers as strata, forming a structure called bedding. (http://en.wikipedia.org/)

Some sedimentary rocks are: Limestone, Dolomite, Shale, Phyllite, Sandstone, Claystone, Mudstone etc.

3.3 Metamorphic rocks result from the re-crystallization of pre-existing rocks under changing temperature and pressure conditions. The process of formation is called metamorphism in which profound physical and/or chemical change takes place.

3.3.1 Due to the action of plate tectonics, compression, stress and shearing forces over long periods of time, rocks get compacted into a smaller volume of space. As a consequence, metamorphic rocks are always more dense than their original material, and also much less susceptible to erosional breakdown. (http://earth.rice.edu/mtpe/geo/geosphere/topics/rocks/30_rocks_metamorphic1.html)

Some metamorphic rocks are: Quartzite (converted quartz sandstone), Schist (converted basalt), Gneiss (metamorphosed granite), Marble (compressed limestone or dolomite) etc.

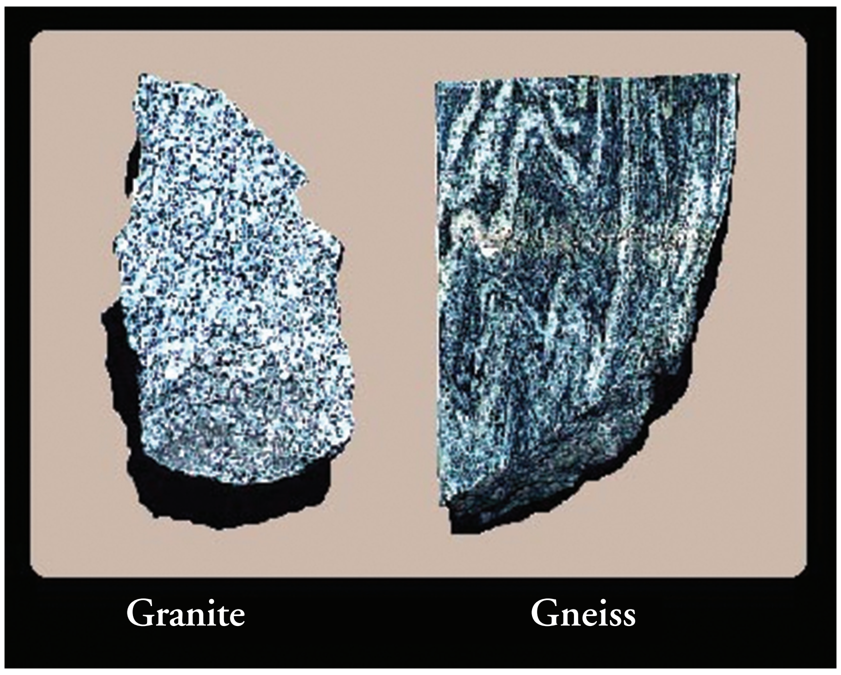

Fig. 1.1 (Source: http://earth.rice.edu/mtpe/geo/geosphere/topics/rocks/30_rocks_metamorphic1.html)

4. **A mineral** is a naturally occurring inorganic substance that is solid, stable at room temperature, and can be represented by a chemical formula. It may be noted that a rock does not have a specific chemical composition, as it can be an aggregate of minerals or non-minerals.

5. Soil Formation – Weathering

Weathering is the process by which rocks and minerals are disintegrated near earth's surface to form soils. It is thus natural that soils inherit their particular texture from the parent materials from which they originates. The process of soil formation through weathering, however, takes a long time. In fact, it can take over 500 years to form just one centimetre of soil from some of the harder rocks. Weathering is an in situ process and does not involve movement of rocks and minerals.

5.1 Different processes of weathering

Depending on the agencies of weathering, the process of weathering may be classified into three types, namely, Physical or Mechanical weathering, Chemical weathering, and Biological weathering. Often all these three processes work simultaneously.

5.1.1 Physical weathering

In mechanical or physical weathering, the parent materials are broken down by agents like heat, water, ice and pressure. During the process, while the rocks undergo physical disintegration, their chemical properties remain unaltered. In cold regions, water that is collected in cracks and crevices of rocks freeze to form ice in winter. The resulting increase in volume generates pressure and facilitates further disintegration of rocks. In hot climatic regions, the variation in temperature between day and night causes disintegration of rocks. Rocks are heated up during the day. But since they are very poor conductor of heat, while outer surface of rocks cools quickly during the night or when exposed to sudden rain, the inner mass takes a longer time to cool. The difference between surface and inside temperature results in peeling off of the rock surface. Mechanical weathering also occurs, when clay or any other material swells on absorption of moisture and causes disintegration of the surrounding rocks.

5.1.2 Chemical weathering

Chemical weathering is the decomposition of rocks caused by a series of chemical processes that include acidification, dissolution and oxidation. Chemical weathering changes the constituents of rocks and soil. When carbon dioxide from the air or soil combines with water, a weak acid known as carbonic acid is formed. While being weak, carbonic acid is very effective in dissolving limestone. As this acid percolates through limestone underground, it can produce huge cracks or hollows. Chemical weathering also occurs when iron contained in rocks is oxidized to form rust. The rust expands and generates pressure to weaken the rock and break it apart. The process of dissolution also causes chemical weathering. Some of the constituent materials of rocks like gypsum, etc are soluble in water. When such materials get dissolved, the rock mass is rendered porous and prone to disintegration. Besides being active as a solvent, water is also responsible for hydrolysis which causes chemical breakdown of materials.

5.1.3 Biological weathering

Biological weathering is caused by plants, animals and microbes. Plant roots, as they grow, break apart the rocks. Though the process is physical in nature, the causal factor, that is, development of roots, is biological. Biological agents also lead to chemical weathering. Plant roots or microorganisms produce organic acids which take part in dissolving minerals. Microbial activity also brings about changes in the chemical composition of rocks and makes it more prone to disintegration. Burrowing animals by virtue of their movement exposes the rocks and minerals to more intimate contact with the various agencies of weathering and thus enhance the process of disintegration.

Although physical, chemical, and biological weathering is separate processes, some or all of the processes can act together in nature.

6. Soil profile and Horizons

6.1 Soil is comprised of minerals, soil organic matter (SOM), water, and air. The pore space is occupied by water and air, whereas soil solids comprise of minerals and SOM.

6.2 As soil formation process progresses, the parent material becomes the habitat of plants and animals, and in the process, gets differentiated into more or less distinct horizontal zones or **soil horizons**.

6.3 A **soil horizon** constitutes a distinct layer of soil. The horizon runs roughly parallel to the soil surface and is characterized by properties distinct from those of the adjacent layers above and below. is a The vertical section of the soil that shows all of its horizons is called the **soil profile**. The soil profile extends from the soil surface to the parent rock material.

(Source: http://www.ctahr.hawaii.edu/mauisoil/a_profile.aspx)

6.4 Soil Horizons (Source: http://www.ctahr.hawaii.edu/mauisoil/a_profile.aspx ; Forest Ecology by Burton V Barnes et.al)

A typical forest soil profile has five zones, called master horizons. However, all soil profiles do not have all five horizons; and so, soil profile differs from place to place. The five master horizons are represented by the letters: O, A, E, B, and C. Please see **Fig. 1.2.**

O: The O horizon is the top surface horizon. It consists of organic material at various stages of decomposition. It is an attribute most unique to forest soils. Materials in this horizon are predominantly those which have fallen from trees, that is, leaves, twigs, flowers, fruits, cones, seeds etc. It has high organic matter content (> 20 or even 30%)

A: The A horizon is a surface horizon that largely consists of minerals (sand, silt, and clay) and with appreciable amounts of organic matter (4 to 12 %). A horizon is thin in most forest soils. This horizon is predominantly the surface layer of many soils in grasslands and agricultural lands.

E: The E horizon is a subsurface horizon that has been heavily leached. Leaching is the process in which soluble nutrients are lost from the soil due to precipitation or irrigation. The horizon is typically light in color. It is generally found beneath the O horizon. This horizon is more acidic than the adjacent horizons.

B: The B horizon is a subsurface horizon. It is formed by accumulation of materials leached and migrated from either A or E horizon.

C: The C horizon is a subsurface horizon which has undergone very little weathering. It is unconsolidated, loose parent material.

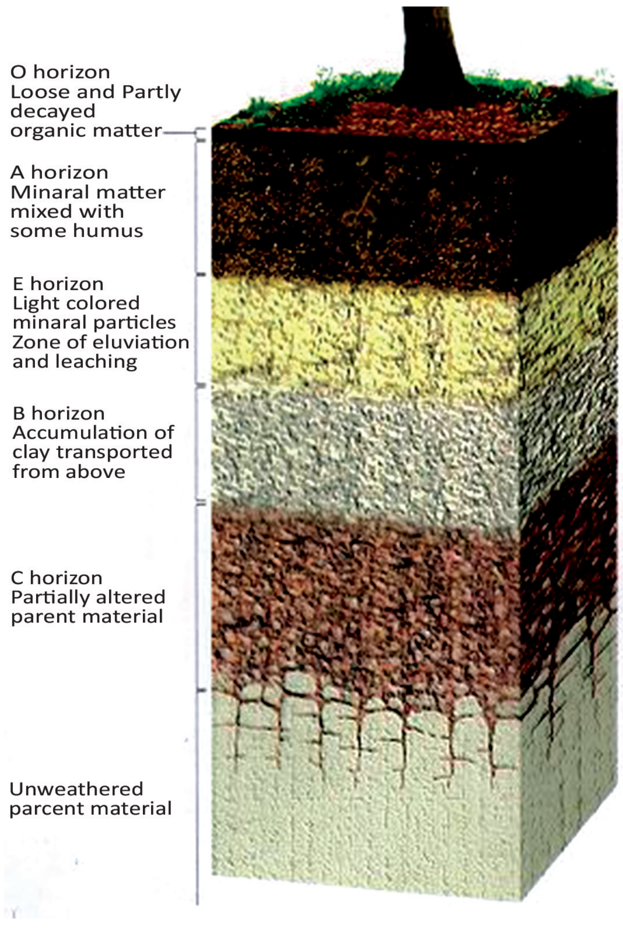

Fig. 1.2 A typical forest soil profile.

(Source: http://www.ctahr.hawaii.edu/mauisoil/a_profile.aspx)

Reference materials:

(1) Burton V. Barnes, Donald R. Zak, Shirley R. Denton, Stephen H. Spurr, Forest Ecology (John Wiley & Sons, Inc. 1998)

(2) Introductory Soil Science by S S Negi, (Bishen Singh Mahendra Pal Singh Dehradun)

(3) http://www.ctahr.hawaii.edu/mauisoil/a_profile.aspx

(4) http://www.ifs.ac.lk/pdf/lectures/geo/Weathering%20and%20soil.pdf

(5) http://passel.unl.edu/pages/informationmodule.php?idinformationmodule=1124303183&topicorder=5&maxto=6

(6) Websites cited in the Lesson

Lesson-2

SOIL SCIENCE

Time 1 hour

Lesson Plan

Objective:

- To study soil properties – physical and chemical Backward linkage:
- Soil formation in Lesson 1 Forward Linkage:
- Chemical and Biological Properties in Lesson 3.

Training materials required:

- Copy of lesson 2 to be circulated beforehand.

Allocation of Time:

- Physical properties - general – 5 min
  - Texture – 10 min
  - Structure – 10 min
  - Porosity – 5 min
  - Soil water – 5 min
- Chemical properties
  - Macro and micro nutrients – 5 min
  - Cation Exchange Capacity – 10 min
- Discussion/ miscellaneous – 10 min

1. Physical properties of Soil

Soil is comprised of minerals, soil organic matter (SOM), water, and air. The composition and proportion of these components greatly influence soil physical properties, including texture, structure, and porosity. In turn, these properties affect air and water movement in the soil, and thus the soil's ability to function (source: Soil and Water Management Module I, Montana State University, Basic Soil Properties).
Physical properties of soil greatly influence

- Supply of water and nutrients to the plants;
- Supply of oxygen to the roots
- Anchorage of stem.

2. Soil Texture

Soils consist of mineral particles whose sizes vary over a wide range. These particles are, however, divided into three size classes, namely, sand, silt and clay. The sizes of these classes are as shown below.

Soil Particles	Diameter in mm
Sand	2.00 to 0.02
Silt	0.02 to 0.002
Clay	< 0.002

Soil texture refers to relative proportion of sand, silt and clay-sized particles contained in a particular soil (Forest Ecology by Burton V Barnes et.al).

2.1 Soil particles of different size classes have distinct physical and chemical properties. **Sand and silt** sized particles which inherit chemically properties from their parent material are called **primary minerals**. The clay fraction of soil contains **secondary minerals** which is produced by physical and chemical weathering of primary minerals.

2.2 Based on the relative content of sand, silt and clay, soils are grouped into different **textural classes.**

- **Loam** - consists of equal proportions of sand, silt and clay.
- **Clay** - 60 % of particles less than .002 mm in diameter.
- **Sand** - more than 90% of the particles are in the diameter range of 0.02 to 2.00 mm.

3. Soil Colloids

'Soil colloids' refer to the finest clay and SOM particles in a soil. Colloids have characteristics that make them the location of most physical and chemical activity in the soil. One of the characteristics is their large surface area because of their finer size. Due to large surface area, there is increased contact with other colloids and with the soil solution. This results in the formation of strong friction and cohesive bonds between colloid particles and soil water. That explains why a clay soil holds together better than a sandy soil when wet. (Source: Soil and Water Management Module I, Montana State University; Basic Soil Properties by Ann McCauley, Soil Scientist, Clain Jones, Extension Soil Fertility Specialist and Jeff Jacobsen, Soil Scientist)

Figure 2.1 Top soil exhibiting granular structure.
(Source: Soil and Water Management Module I, Montana State University; Basic Soil Properties by Ann McCauley, Soil Scientist, Clain Jones, Extension Soil Fertility Specialist and Jeff Jacobsen, Soil Scientist)

4. Soil structure

(Source: Soil and Water Management Module I, Montana State University, Basic Soil Properties by Ann McCauley, Soil Scientist, Clain Jones, Extension Soil Fertility Specialist and Jeff Jacobsen, Soil Scientist)

Soil structure is the arrangement and binding together of soil particles into larger clusters, called **aggregates or peds.** Aggregation is important for increasing stability against erosion, for maintaining porosity and soil water movement, and for improving fertility and carbon sequestration in the soil.

4.1 Aggregates may range from single-grain structure (e.g. beach sand) to a massive one (having high clay content). Plants prefer aggregation that lies in the middle of this range. In the mid range also the form of aggregates varies from granules (several mm in diameter) to blocks, prisms etc.(several cm in size).

4.2 'Granular' structure consists of loosely packed spheroidal peds that are glued together mostly by organic substances (**Figure 2.1**). Granular structure is characteristic of many A horizons, particularly those with high SOM content and biological activity. Larger peds, in the form of plates, blocks, or prisms, are commonly associated with the B horizon.

As soil swells (wets or freezes) and then shrinks (dries or thaws), cracks form around soil masses, creating peds. Peds are held together in place through the adhesion of organic substances, iron oxides, clays or carbonates. Cracks and channels between peds are important for water, air, and solute transport and deep water drainage. Finer soils usually have a stronger, more defined structure than coarser soils.

5. Soil porosity

A soil's porosity and pore size distribution characterize its pore space, that portion of the soil's volume that is not occupied by or isolated by solid material. Porosity is the fraction of the total soil volume that is taken up by pore space. Thus it is a single value quantification of the space available to fluid within a specific body of soil. Typical values for soil porosity are between 0.3 and 0.7 (Porosity and Pore Size Distribution by J.R Nimmo, US. Geological Survey at http://wwwrcamnl.wr.usgs.gov/uzf/abs_pubs/papers/nimmo.04.encyc.por.ese.pdf).

5.1 Many important soil processes take place in soil pores (the air or water-filled spaces between particles). Soil texture and structure influence porosity by determining the size, number and interconnection of pores. Coarse-textured soils have many large (macro) pores because of the loose arrangement of larger particles with one another. Fine-textured soils are more tightly arranged and have more small (micro) pores. Macro-pores in fine-textured soils exist between aggregates. Because fine-textured soils have both macro- and micro- pores, they generally have a greater total porosity, or sum of all pores, than coarse-textured soils. (Source: Soil and Water Management Module I, Montana State University)

5.2 Unlike texture, porosity and structure are not constant and can be altered by management, water and chemical processes. In general, increasing SOM levels, reducing the extent of soil disturbance, and minimizing compaction and erosion will increase soil porosity and improve structure.(Source: Soil and Water Management Module I, Montana State University)

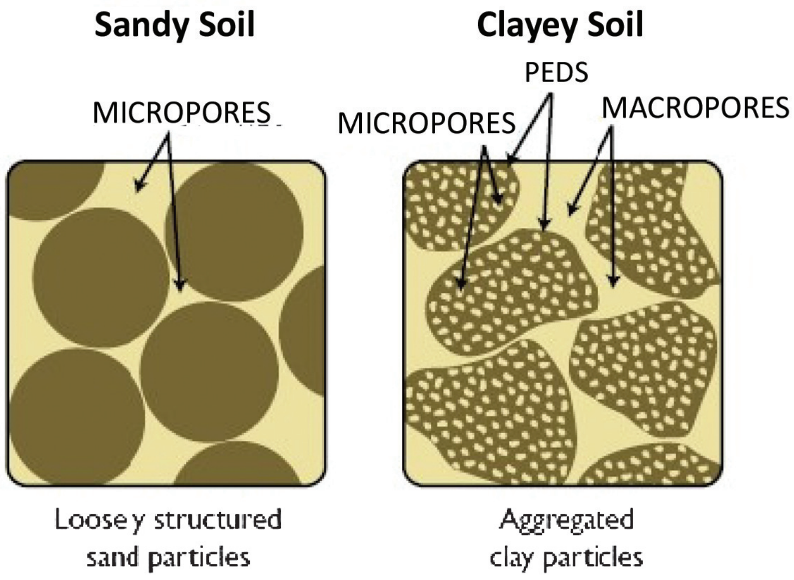

Fig.2.2 Porosity in sandy and clayey soils
(Source: Soil and Water Management Module I, Montana State University, Basic Soil Properties by Ann McCauley, Soil Scientist, Clain Jones, Extension Soil Fertility Specialist and Jeff Jacobsen, Soil Scientist)

6. Soil water and Plant Relations

Distribution of vegetation on earth is controlled by water availability, that is, amount of water which is available to plants. First of all, the prerequisite for forests to occur in a region is that the precipitation should be in excess of water loss due to evaporation. But the amount of water (out of total quantity available) that individual plants can utilize is influenced by interaction of water molecules with soil particles.

6.1 Soil texture and properties dependent on texture, like porosity, control the movement of water and air in the soil, which in turn affect use of water by plants and their growth. As soil becomes dry or wet, the proportion of pore space occupied by water and by air varies. When all pores are filled with water, the soil is 'saturated', and water within macropores will drain freely from the soil via gravity. 'Field capacity' (FC) is the amount of water remaining in the soil after all gravitational water has drained. This remaining water is held in micro-pores under attractive 'capillary' forces or surface tension between water and solids. Unlike gravitational water, capillary water is retained in the soil and can only be removed by plant uptake or evaporation. The amount of capillary water that is available to plants is the soil's 'water holding capacity' (WHC) or 'plant available water' (PAW). This water is available for plant uptake until the 'permanent wilting point' (PWP) is reached, a point at which water is held too tightly by the soil for plants to extract it. (Soil and Water Management Module I, Montana State University)

7. Chemical properties of Soil

The table below shows the elements, called **macro-nutrients,** which construct the plant life. The table also shows the sources from which plants draw these elements.

Macro-nutrient Elements Required by Plants and their Source within Terrestrial Ecosystems

Element	Symbol	Source
Carbon	C	Atmosphere
Hydrogen	H	Water
Oxygen	O	Atmosphere, water
Nitrogen	N	Organic matter, atmosphere
Phosphorus	P	Mineral soil, organic matter
Potassium	K	Mineral soil, organic matter
Sulphur	S	Mineral soil, organic matter, atmosphere
Magnesium	Mg	Mineral soil
Calcium	Ca	Mineral soil

(Source: Forest Ecology by Burton V Barnes et.al)

Each of the macro-nutrients, in varying quantities, is required for plant growth. These elements are called **macro-nutrients**, as they are required in relatively large amounts. In contrast, **micro- nutrients** are those elements which are required in relatively small amounts. These include **Boron (B), Copper (Cu), Iron (Fe), Chlorine (Cl), Manganese (Mn), Molybdenum (Mo) and Zinc (Zn)**. Although required in small quantities, the micro-nutrients are essential for the plants. Though plants get carbon and oxygen from the atmosphere, the majority of macro and micro-nutrients are supplied by the soil.

7.1 Cation Exchange Capacity

(Source: Cornell University Cooperative Extension – Agronomy Fact Sheet Series,Fact Sheet 22)

7.1.1 Cations are positively charged ions such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), sodium (Na^{+}) hydrogen (H^{+}), aluminum (Al^{3+}), iron (Fe^{2+}), manganese (Mn^{2+}), zinc (Zn^{2+}) and copper (Cu^{2+}). The capacity of the soil to hold on to these cations is called the **cation exchange capacity (CEC)**. CEC is a general measure of plant nutrient availability.

7.1.2 The cations are held by the negatively charged clay and organic matter particles in the soil through electrostatic forces (negative soil particles attract the positive cations). Please see the **Fig.2.3**. The cations on the CEC of the soil particles are easily exchangeable with other cations and as a result, they are plant available. Thus, the CEC of a soil represents the total amount of exchangeable cations that the soil can adsorb. These adsorbed cations serve as a reservoir of plant nutrient in soil. **The cations used by plants in the largest amounts are calcium, magnesium, and potassium.**

7.1.3 Why do soils have a CEC?

Soils have a CEC primarily because clay particles and organic matter in the soil tends to be negatively charged. Since the soil as a whole does not have electric charge, the negative charge of the clay particles is balanced by the positive charge of the cations in the soil.

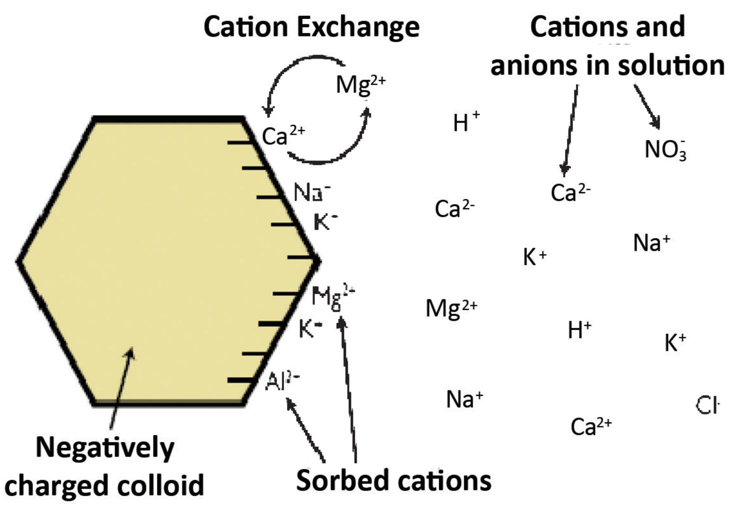

Fig. 2.3 Simplified representation of exchange capacity

(Source: Soil and Water Management Module I, Montana State University, Basic Soil Properties by Ann McCauley, Soil Scientist, Clain Jones, Extension Soil Fertility Specialist and Jeff Jacobsen, Soil Scientist)

7.1.4 Units

The CEC of a soil is expressed in $cmol_C/kg$ (centimol positive charge per kg of soil) or meq/100 g (milli-equivalents per 100 grams of soil). Both expressions are numerically identical (10 $cmol_C/kg$=10 meq/100 g).

7.1.5 Implications

- The higher the CEC the more clay or organic matter present in the soil. This usually means that high CEC (clay) soils have a greater water holding capacity than low CEC (sandy) soils.
- Low CEC soils are more likely to develop potassium and magnesium (and other cation) deficiencies, while high CEC soils are less susceptible to leaching losses of these cations.
- The lower the CEC, the faster the soil pH will decrease with time. So, sandy soils need to be limed more often than clay soils.
- The higher the CEC, the larger the quantity of lime that must be added to increase the soil pH; sandy soils need less lime than clay soils to increase the pH to desired levels.

Reference materials:

(1) Burton V. Barnes, Donald R. Zak, Shirley R. Denton, Stephen H. Spurr, Forest Ecology (John Wiley & Sons, Inc. 1998)

(2) Soil and Water Management Module I, Montana State University, Basic Soil Properties by

Ann McCauley, Soil Scientist, Clain Jones, Extension Soil Fertility Specialist and Jeff Jacobsen, Soil Scientist

(3) Porosity and Pore Size Distribution by J.R. Nimmo, US. Geological Survey at http://wwwrcamnl.wr.usgs.gov/uzf/abs_pubs/papers/nimmo.04.encyc.por.ese.pdf

(4) Cornell University Cooperative Extension – Agronomy Fact Sheet Series, Fact Sheet 22

(5) Websites cited in the Lesson

Lesson-3

SOIL SCIENCE

Time 1 hour

Lesson Plan

Objective:

- To study soil properties – chemical and biological Backward linkage:
- Soil properties in Lesson 2 Forward Linkage:
- Soil Testing described in Lesson 5.

Training materials required: Copy of lesson 3 to be circulated beforehand.

Allocation of Time:

- Chemical properties
  - pH – 25 min
- Soil organic matter – 10 min
- Biological properties – 15 min
- Discussion/ miscellaneous – 10 min

Chemical Properties of Soil Continued

1. Soil pH

Soil pH is commonly used to quantify acidity and, by definition, is the negative logarithm of the hydrogen ion concentration in soil solution (Forest Ecology by Burton V Barnes et.al).
Thus pH = - log [H^+]

Please note that

- **in the above relation log is to the base 10. Some examples of log values are:**
  $\log_{10}10 = 1$, $\log_{10}10^2 = 2$, $\log_{10}10^5 = 5$, $\log_{10}10^{-7} = -7$ etc.
- **Hydrogen ion concentration [H^+] is to be expressed in moles per litre.** [The mole is defined as the amount of substance that contains as many elementary entities (e.g., atoms, molecules, ions, electrons) as there are atoms in 12 g of carbon.] 1 mol/L means a solution in which 1 mole of hydrogen ions is present in 1 litre.

1.1 pH scale

A solution with a concentration of hydrogen ions higher than 10^{-7} mol/L is acidic, and a solution with a lower concentration is alkaline (another way to say basic). Using the above formula, a pH of 7 is neutral, a pH less than 7 is acidic, and a pH greater than 7 is basic. The

pH scale goes from 0 to 14 with pH 7 as the neutral point. As the amount of hydrogen ions in the soil increases, the soil pH decreases thus becoming more acidic. From pH 7 to 0 the soil is increasingly more acidic and from pH 7 to 14 the soil is increasingly more alkaline or basic.

1.2 Influence of pH

On plant growth – Soil pH or soil acidity affects the solubility of soil minerals and thus influences the availability of nutrients for plant growth. Neutral pH value (that is pH near 7) is ideal for maximum availability of most plant nutrients.

On weathering – As it influences the solubility of soil minerals, soil pH or soil acidity has an impact on (1) the rate at which the parent material undergoes weathering, (2) the process of formation of clay minerals, and (3) soil development.

1.3 Measurement of soil pH

(Source: Methods Manual, Soil Testing in India, Department of Agriculture & Cooperation Ministry of Agriculture, Government of India, New Delhi, January, 2011)
The procedure for measurement of soil pH is given below.

Apparatus

- pH meter with a range of 0-14 pH
- Pipette/dispenser
- Beaker
- Glass rod

Reagent

- Buffer solutions of pH 4, 7 and 9
- Calcium chloride solution (0.01M): Dissolve 14.7 g $CaCl_2.2H_2O$ in 10 litre of water to obtain 0.01M solution.

Procedure

1. Calibrate the pH meter, using 2 buffer solutions, one should be the buffer with neutral pH (7.0) and the other should be chosen based on the range of pH in the soil. Take the buffer solution in the beaker. Insert the electrode alternately in the beakers containing 2 buffer solutions and adjust the pH. The instrument indicating pH as per the buffers is ready to test the samples
2. Weigh10.0 g of soil sample into 50 or 100 ml beaker, add 20 ml of $CaCl_2$ solution (use water instead of $CaCl_2$ solution throughout the procedure if water is used as a suspension medium).
3. Allow the soil to absorb $CaCl_2$ solution without stirring, then thoroughly stir for 10 second using a glass rod.
4. Stir the suspension for 30 minutes and record the pH on the calibrated pH meter.

Based on soil pH values, following types of soil reactions are distinguished:

PH Range	Soil Reaction Rating
<4.6	Extremely acidic
4.6-5.5	Strongly acidic
5.6-6.5	Moderately acidic
6.6-6.9	Slightly acidic
7.0	Neutral
7.1-8.5	Moderately alkaline
>8.5	Strongly alkaline

2. Soil Organic matter (SOM)

(Source: Forest Ecology by Burton V Barnes et.al)

Reference to SOM has come in our lessons in relation to description of soil properties. It is, however, felt necessary to dwell upon the subject in a little more details. SOM composes a relatively small fraction of most forest soils - < 1 % to 15% (Forest Ecology by Burton V Burnes et.al). SOM is also known as “plant litter”.

2.1 Function

SOM

- Plays an active role in aggregate formation, which again determines the amount of soil water that would be available to plants;
- Supplies most of the Nitrogen necessary for the growth of plants;
- Has a critical role for growth and maintenance of microbial populations in the soil; metabolic activities of these organisms lead to release of nitrogen and other plant nutrients from SOM.

2.2 Sources

SOM originates from plant litter both above and below the ground.

- Above ground sources – leaves, flowers and fruits, twigs and tree stems;
- Belowground sources – roots

In soils the above compounds are metabolized by micro-organisms, producing energy, CO_2, H_2O and humus as end products.

2.3 Humus

As the constituent materials of SOM get metabolized by micro-organisms, humus is produced. Humus forms the highly decomposed organic layer of O horizon in the soil profile. A complex and chemically-resistant material humus gives surface soils their dark colour and unique chemical properties. As it is in an advance state of decay, humus does not resemble the parent material it has come from. Resistant to further changes it can accompany the soils for long periods of time. With a net negative charge humus can prompt cation exchange reactions, and thus can influence nutrient availability in soil.

3. Biological Properties

(Source: Soil and Water Management Module 1, Basic Soil properties, Montana State University)

3.1 Soil Biota

The soil environment is teeming with biological life and is one of the most abundant and diverse ecosystems on earth. Soil biota, including flora (plants), fauna (animals) and microorganisms, perform functions that contribute to the soil's development, structure and productivity. General characteristics and functions of these groups are presented below.

3.2 Soil Flora

Plants act on the soil environment by aiding in structure and porosity, and in supplying SOM via shoot and root residue. Root channels can remain open for some time after the root decomposes, allowing an avenue for water and air movement. Roots also act to stabilize soil through aggregation and intact root systems can decrease soil loss. The 'rhizosphere,' the narrow zone of soil directly surrounding plant roots, is the most biologically active region of the soil. It contains sloughed root cells and secreted chemicals (i.e., sugars, organic acids) that provide organisms with food.

3.3 Soil Fauna

Soil fauna work as soil engineers, initiating the breakdown of dead plant and animal material, ingesting (taking as food) and processing large amounts of soil, burrowing 'biopores' for water and air movement, mixing soil layers, and increasing aggregation. Important soil fauna include earthworms, insects, nematodes, arthropods and rodents. Earthworms are considered one of the most important soil fauna. Through the process of burrowing, they provide channels that increase a soil's porosity, WHC, and water infiltration. They also increase further biotic activity by breaking down large amounts of SOM through digestion and supplying nutrient-rich secretions. Furthermore, earthworms are able to build soil by moving between 1 to 100 tons of subsoil per acre per year to the surface, possibly helping offset losses by erosion.

3.4 Soil Microorganisms

Microorganisms (microbes) are invisible to the naked eye. However, their effect on numerous soil properties is far-ranging. Microorganisms represent the largest and most diverse biotic group in soil, with an estimated one million to one billion microorganisms per one gram of agricultural top soil. Microbes aid soil structure by physically surrounding particles and 'gluing' them together through the secretion of organic compounds, mainly sugars. This contributes to the formation of granular structure in the A horizon where microbial populations are greatest. Soil microbes include **bacteria, protozoa, algae, fungi and actinomycetes.** Bacteria are the smallest and most diverse soil microbes. Bacteria are important in SOM decomposition, nutrient transformations and small clay aggregation. Some bacteria carry out very special roles in the soil, such as Rhizobia (plural form of Rhizobium), the nitrogen-fixing bacteria associated with legume roots. Protozoa (e.g., amoebas, ciliates, flagellates) are mobile organisms that feed on other microbes and SOM. Algae, like plants, photosynthesize and are found near the soil surface. Fungi are a diverse group of microbes that are extremely important in the breakdown of SOM and large aggregate stability. Many fungi have long 'hyphae' or 'mycelia' (thin thread- like extensions) that can extend yards to miles underneath the soil surface and physically bind soil particles. Actinomycetes are a microbial group that are classified as bacteria, but have hyphae similar to fungi. They are important for SOM breakdown, particularly the more resistant fractions, and give soil much of its 'earthy' odor. Bacteria dominate in agricultural and grassland soils, whereas fungi are more prevalent in forest and acid soils.

3.4.1 An important relationship found in almost all soils and plants, including many crop species, are mycorrhizae. Mycorrhizae are a plant-fungal symbiosis (a relationship between two interacting species) in which fungi infect and live in, or on, a plant root. The fungus depends on the plant for energy, and in return, the fungus and its hyphae can take up nutrients for the plant, and possibly improve plant growing conditions.

3.5 Biological Activity

Soil biological activity is controlled by many factors in the soil. SOM quantity and quality, primarily nitrogen (N) content, are major limiting factors for soil organism activity. Other soil factors that promote activity are adequate levels of oxygen, near-neutral pH, temperatures between 85-95°F, and 50-60% moisture. Combinations of these factors will result in maximum activity. Although some organisms have adapted to extreme environmental conditions, overall activity generally diminishes when conditions fall outside of these ideal ranges.

Reference materials:

(1) Burton V. Barnes, Donald R. Zak, Shirley R. Denton, Stephen H. Spurr, Forest Ecology (John Wiley & Sons, Inc. 1998)

(2) Soil and Water Management Module I, Montana State University, Basic Soil Properties by Ann McCauley, Soil Scientist, Clain Jones, Extension Soil Fertility Specialist and Jeff Jacobsen, Soil Scientist

Lesson-4

SOIL SCIENCE

Time 1 hour

Lesson Plan

Objective:

- To study major soil types in India
- Agro-Ecological Classification of soils in West Bengal
- Soil problems in West Bengal

Backward linkage:

- Soil properties in Lesson 2 and 3

Forward Linkage:

- To show the trainees during tour the vegetation and soil types of different bio- geographic zone.

Training materials required:

- Copy of lesson 4 to be circulated beforehand.

Allocation of Time:

- ▪ Major soil types of India – 25 min
- Agro-Ecological Classification of soils in West B – 10 min
- Soil problems in West Bengal – 15 min
- Discussion/ miscellaneous – 10 min

1. Major Soil Types in India

(Source: India-the land and people, Land and Soil by Dr. S P Raychaudhuri, Introductory Soil Science by S S Negi, Methods manual – Soil Testing in India, Deptt of Agriculture and Cooperation, Ministry of Agriculture, GoI, Jan 2011, http://www.yourarticlelibrary.com/soil/soil-groups-8-major-soil-groups - available-in-india/13902/)

Some dominant groups of Indian soil, classified according to soil taxonomy and chemical property are as follows.

1) Alluvial soil
2) Black soil (regur)
3) Red soil
4) Laterite and lateritic soil
5) Forest and Hill soil
6) Desert Soil

1.1 In addition, there are soil types, which are identified as problem soils. According to salt content, they are classified as follows.

(i) Saline and Alkali Soil
(ii) Acid Soil
(iii) Peaty and Marshy Soil

1.2 Alluvial Soil

Alluvial soil is by far the largest and most important soil group of India, contributing the largest share to the agricultural wealth of the country. These soils cover about 1,500,000 square kilometers. Over this large tract, however, lots of subordinate variations of alluvial type are exhibited. Main features of this alluvial soil are derived from the deposition and silt brought in by the numerous river systems. The most important of alluvial deposit is the Indo-Gangetic plain. Geologically, the alluvium is classified into two groups, namely. (1) Khadar, i.e newer alluvium of sandy, generally light coloured, and less kankary composition, and (2) Bhangar, i.e older alluvium of more clayey composition, generally of dark coloured and full of kankar.

1.2.1 In West Bengal, portion of Murshidabad, Bankura, almost the whole tract known as Rarh region are composed mainly of the old alluvium, while the remaining alluvial soil in the state consists of relatively recent alluvium. The latter class of soil is more fertile and productive. The texture of the recent alluvium varies from sandy loam to clay and at certain horizons gives rise to clay pan.

1.2.2 Characteristics

- Coarse in upper section, finest in delta
- Rich in potash and humus, but poor in phosphorus and Nitrogen; deficiency in Nitrogen often is the limiting factor in crop production.
- Very fertile soil, suitable for all kinds of crops (kharif and rabi)
- Occurrence in Punjab, Haryana, UP, Bihar, WB, parts of Orissa, Assam, delta regions of Southern part of India.

1.3 Black Soil (regur)

Black soil is also known as regur or black cotton soil. Dark grey to black in colour, black soil is derived from the Deccan trap (weathering of the deccan lava) and is common in Maharashtra, western part of Madhya Pradesh, Andhra Pradesh, Gujarat, parts of Karnataka, and parts of Tamil Nadu. It also occurs in parts of Uttar Pradesh and Rajasthan. Black soil covers an area of about 546,000 km^2

1.3.1 Characteristics

- Clay content is high, exceedingly sticky when wet;
- Rich in lime, iron, calcium and magnesium carbonates, magnesia and alumina;
- Poor in phosphorus, nitrogen and organic matter;
- Highly suitable for cotton;

1.4 Red soils

Red soils have originated from weathering of the ancient crystalline and metamorphic rocks. They occupy good portions of Tamil Nadu, Karnataka, south-east Maharashtra, east of Andhra Pradesh, Madhya Pradesh and Chota Nagpur covering a total area of about 350,000 km^2. In the north, the red soil area extends into and includes the greater part of Santhal Parganas in Jharkhand, the Birbhum district of West Bengal, and the Mirzapur, Jhansi and Hamirpur districts of Uttar Pradesh.

1.4.1 Characteristics

- More sandy and less clayey;
- Generally poor in nitrogen, phosphorous and humus;
- In comparison with regur (black soil), poorer in lime, potash and iron oxide;
- Suitable in general for cultivation of ragi, groundnut, millet, potato, tobacco, paddy, wheat and sugarcane.

1.5 Laterite and Lateritic soil

Formation of this soil is typical of India and some other tropical countries with intermittently moist climate. It is a compact to vesicular rock composed, essentially of a mixture of the hydrated oxides of aluminium and iron with small amounts of manganese oxides, titania (titanium dioxide) etc. They cover a total area of about 248,000 km^2. Laterite may disintegrate and get carried down by the stream flow. When re-deposited at lower levels, the laterites may become cemented again to form compact mass.

1.5.1 Occurrence

- Laterites are well developed on the summits of hills of Karnataka, Kerala, Madhya Pradesh, the eastern ghat regions of Orissa and West Bengal, south Maharashtra, Malabar coast and parts of Assam
- Laterite and lateritic soils are found in Kerala, Orissa, West Bengal, Maharashtra and Assam.
- In West Bengal lateritic soils occur in the districts of Birbhum, Burdwan, Bankura and Paschim Medinipur

1.5.2 Characteristics

- Lateritic soil is generally poor in available nutrients of nitrogen, phosphorus, potassium and calcium.
- The pH ranges from 4.8 to 5.5; consequently they give high response to application of lime and potash.

1.6 Forest and Hill Soil

Formation of forest soil is governed by deposition of organic matter derived from forest growth. Forest soil covers an area of about 285,000 km^2. The scenario is complex as different soil climates occur on hills and in plains.

1.6.1 Occurrence

Such soils are mainly found on the hill slopes covered by forests. In the Himalayan region, they mainly occur in valley basins, depressions, and in easy and moderate slopes. Apart from the Himalayan region, the forest soils occur on Western and Eastern Ghats as well as in some parts of the peninsular plateau. The surface layer of cinchona-growing soils in the Darjeeling district of West Bengal consists of well-decomposed humus and mineral soil.

1.7 Desert Soils

A large part of the arid and semi-arid region belonging to Rajasthan, southern part of Punjab and Haryana and north Gujarat, covering an area of about 142,000 km^2 is affected by desert condition. The region is characterized by scanty rainfall and high rate of evaporation. The soil in this region is covered by a mantle of sand which inhibits soil growth.

1.7.1 Characteristics

- Some of these soils contain high percentage of soluble salts, are alkaline (high pH) and are poor in organic matter;
- The soils may be reclaimed on proper irrigation

1.8 Saline and Alkali Soils

The distribution of saline and alkaline soils is extensive throughout India in all climatic zones. Many parts of the North, especially **Bihar, Uttar Pradesh, Punjab, Haryana and Rajasthan**, give rise to saline and alkaline efflorescence. The alluvial clays and silts still contain many mineral fragments which are undecomposed. On weathering, they liberate sodium, magnesium and calcium salts in the soils. Large areas, once fertile and populous, have become impregnated with these salts locally known as *reh* or *kalkar* with very harmful effect on their fitness for cultivation. Alkali soils are met with all over the states of Gujarat and Maharashtra, but badly affected lands are found in Gujarat, Karnataka and the Deccan.

1.8.1 Characteristics

- Contain salts of sodium, Calcium and Magnesium
- Infertile and unfit for cultivation
- Sandy to loamy in texture

1.9 Acid Soils

In India about 6.5 million hectares of land area is covered by strongly acid soils ($pH < 5.5$). The acid soil areas occur in and around Bhawali (UP), Palampur, Kangra (HP), Baster and Jagdalpur (Chhattisgarh), Jorhat and Titabar (Assam), Ratnagiri (Maharashtra) and large areas in Ooty (Tamil Nadu) and Kutanad (Kerala). The acid soils suffer due to lack of calcium and magnesium and in some cases due to aluminium and iron toxicity. However, these soils are being cultivated and their productivity can be improved when limed.

1.10 Peaty and Marshy Soil

Peaty soils originate in humid regions as a result of accumulation of large amounts of organic matter in the soil. They may also contain considerable amounts of soluble salts. Typical pity saline soil (kari) covering an area of about 150 km^2 have been observed in Kuttanad in Kerala. The soils are generally submerged under water during the monsoon. After the rains, these are put under paddy cultivation. Soils are black, heavy and highly acidic, with pH as low as 3.9, and contain 10-40 per cent of organic matter. Their acidity is due to the decomposition of organic matter under anaerobic conditions. The depression formed by dried river-basins and lakes in alluvial and coastal areas sometimes give rise to peculiar waterlogged and anaerobic conditions of the soils. Marshy soils of this type are found in the coastal tracts of Orissa, the Sunderbans and some other places in West Bengal, central portion of north Bihar, Almora district of Uttarakhand, and south-east coast of Tamil Nadu.

2. Agro-Ecological Classification of soils in West Bengal (Source: State Forest Report WB 2006-07)

The agro-ecological classification of soils in West Bengal may be seen in Appendix I.

3. Soil problems in West Bengal

(Source: Soils of West Bengal for Optimising Land Use, NBSS & LUP 1992; State Forest Report WB 2011-12)

There are different kinds of soil problems, such as soil erosion, soil depth, drainage, salinity, etc. which need be addressed for effective land use planning. The limiting soil attributes, their extent and distribution are briefly described below and in Appendix II.

3.1 Soil Depth

Soil depth is one of the factors to determine the nature of crop that can be grown on a soil. The effective soil depth governs the development of roots and supply of moisture and plant nutrients. The three classes of soil depth affecting crop growth which need be considered in selecting suitable crop are described in Appendix II.

3.2 Internal Drainage

Internal drainage is governed by soil texture, landform situation and depth of water table. The four drainage classes which have been found to affect adversely the soil and crop management are described in Appendix II.

3.3 Erosion

Erosion caused by water is one of the major soil degradation factors in the hilly regions of Darjeeling district and undulating terrains of south western plateau region of the State where extensive areas are affected by gullies. The areas affected by severe and moderate erosion which need measures are described in Appendix II.

3.4 Texture

The three texture classes that hinder crop growth and the areas affected by these classes are described in Appendix II.

3.5 Salinity

Soil salinity in West Bengal is mainly due to the inundation of tidal water in deltaic zone. The reclamation of these soils by removing soluble salts is a major management aspect. The three soil salinity c1asses, viz. very strong, strong and moderate salinity hazards affect the crop growth severely. The areas affected by salinity limitation are given in Appendix II. For management of salinity either the soils need drainage followed by measures to maintain former salt balance in the soil profile.

3.6 Flooding

Surface flooding is a serious limitation for crop production in the Indo-gangetic plains of West Bengal. Among the several flood limitations, the areas affected by moderate and severe flooding are given in Appendix II.

3.7 Waterlogging

Waterlogging is defined as the stage where by the soil becomes saturated by water within the depth of root zone for a significant period. It is considered a serious limitation which adversely affects the yield and quality of crops. Waterlogging may be caused by high ground water table or submergence by rain water or both. The areas affected by waterlogging in West Bengal are given in Appendix II.

Reference materials:

(1) India-the land and people, Land and Soil by Dr. S P Raychaudhuri, (National Book Trust India)

(2) Introductory Soil Science by S S Negi (Bishen Singh Mahendra Pal Singh Dehradun)

(3) Methods manual – Soil Testing in India, Deptt of Agriculture and Cooperation, Ministry of Agriculture, GoI, Jan 2011,

(4) http://www.yourarticlelibrary.com/soil/soil-groups-8-major-soil-groups -available-in-india/13902/)

(5) State Forest Report, West Bengal, 2011-12

Soil Science : Lesson 4

Appendix I

Table – 4.1

AGRO-ECOLOGICAL CLASSIFICATION OF SOILS IN WEST BENGAL

Sl. No.	Agro-Ecological Sub-region	Types of Soil	Climatic Factors	Soil Characteristics	Extent	Range
1	Warm Perhumid	Brown Forest Soil of the Himalayas	Climate warm perhumid, characterized by mild summers and cold winters at an altitude of 150 to 600mts. Above MSL associated with high rainfall.	Soils on steep hill slopes are shallow, excessively drained with severe erosion hazard potential. Soils of the foothill slopes and valleys are moderately deep, well drained, loamy in texture with moderate erosion hazards. Soil with low water holding capacity, moderate to high in organic matter and available Potash but low in available Phosphorus. Low pH causing excess of Manganese and Aluminium deposition in soil but low in Molybdenum and Boron in some places.	Occupies an area of 0.26 m. ha. representing 2.9 per cent of the total area of the State.	Mountainous region of Darjeeling District.
2	Warm to hot Perhumid	Terai soils of the Himalayan foot hills	Warm summer, cool winter, high rainfall	Partly developed, mainly formed of young alluvium on alluvial fans of the foothills. Shallow to moderately deep and at places deep with medium to fine texture. Faces severe flood hazard and runoff problem associated with low water holding capacity of the soil resulting in low pH due to percolation of the alkaline salts and consequent low decomposition of organic matter. Hence, soil contains high amount of undecomposed organic matter; low in available N and P. K is moderate to high.	Occupies an area of 0.17 m. ha. representing 1.9 per cent of the total area of the State.	Northern fringe of Jalpaiguri district, Siliguri and part of Cooch Behar.
3	Hot Perhumid	Alluvial plains of Teesta, Torsa, Mahananda etc.	Warm summer, mild winter associated with high rainfall. Length of Growing period 270 to 300 days.	Moderately deep to deep, coarse to fine, loamy in texture, formed by recent alluvial deposits. Low water holding capacity resulting in low pH low decomposition of organic matter, low N; low CEC. Faces problems of water logging and severe flood hazards.	Occupies an area of 0.85 m.ha. representing 9.6 per cent of the total area of the State.	Districts of Cooch Behar, Jalpaiguri (Southern part) and Islampur subdivision of Uttar Dinajpur (Duars).
4	Hot moist sub-humid	Indo- gangetic Plain (Bengal basin).	Hot moist summer and mild winter, average rainfall 1389 to 1908mm. LGP 210 to 240 days.	Soil formed from the alluvium deposited by Ganga and its tributaries. Varies greatly in their morphological (loamy to clayey loam), physical and chemical properties depending upon their geomorphic situation, moisture regime and degree of profile development. Possesses back swamps in old flood plains with high water table and somewhat poor drainage. pH 5.8 to 8, soil low in available N; P and K moderate.	Occupies an area of 4.39 m. ha. representing 55.7 per cent of the total area of the state	Into-Gangetic plain covering districts of Malda, West Dinajpur (Southern part), Murshidabad, Nadia, Howrah, Hooghly, 24-Parganas (Northern part),

Sl. No.	Agro-Ecological Sub-region	Types of Soil	Climatic Factors	Soil Characteristics	Extent	Range
		Alluvium of Damodar, Kangsabati, Ajoy, Rupnarayan	Hot dry summer moderate winter, Av. Rainfall 1270 to 1520 mm. LGP 150 to 180 days.	Soil formed by alluvial deposts of rivers originating from Chotanagpur plateau. Soil well drained containing basic and ferruginous concretions. PH 5.5 to 7.2; low in organic matter containing low to moderate N and P while moderate to high K content.		Purulia(South-eastern part), Burdwan (Eastern part), Birbhum, Bankura and Midnapore (Eastern part).
5	Moist Sub-humid	Saline Soils (Physiologi cally Dry Soil).	Warm humid summer, mild winter, mean annual rainfall covers 80-90% of evapo-transpiration rate. LGP* 240 to 270 days.	Deep, fine loamy to fine textured soils containing high amount of basic salts of Na., Ca., Mg. etc. and high amount of organic matter with moderate amount of NPK. By and large salt impregnated due to tidal flow of sea water through creeks and sub tributaries. Imperfectly to poorly drained with moderate to very high salinity hazards. Can be divided into four categories, viz. i. Saline Soils; ii. Saline-alkaline Soils; iii. Alkaline Soils; iv. Degraded Alkaline Soils.	Occupies an area of 0.68 m.ha. representing 7.6 percent of the total area of the State.	Coastal parts of the districts of 24-Parganas (South and North) comprising mostly Sundarban areas of South 24-Parganas and Coastal Midnapore.
6	Hot moist sub-humid	Red Lateritic Soil	Hot dry Summer; Cold dry winter. Rainfall 1270 to 1392 mm. LGP 150 to 180 days.	Shallow to deep, reddish to yellowish red, loamy to clayey and imperfectly to well drained. pH 4.8 to 6.6, soil low in organic matter and available phosphorus and minerals.	Occupies an area of 1.98 ha. representing 22.3 percent of the total area along the outliers of the eastern part of Chotanagpur plateau merging to Bengal Basin of Indogangetic Plain.	Districts of Purulia and Western parts of Burdwan, Bankura, Birbhum and Midnapore.
		Gneissic gravelly soil .	Hot dry Summer; Moderate to severe dry winter. Rainfall 900 to 1270 mm. LGP 150 to 180 days.	Topography undulating with low soil depth, surface encrustatious are common; pH low to neutral; low in organic matter. Poor capacity for retention of rainwater leads to severe run off and soil erosion.		North-western part of Purulia, Asansol sub-division of Burdwan, parts of West Midnapore, Bankura and Birbhum

* Leanth of Growing period

Source : State Forest Report, W.B. 2006-2007, Govt. of West Bengal

Appendix-II

Soil Problems in West Bengal

Soils under Limiting Depth Classes

Class	Distribution	Area affected (.000 ha.)
Very shallow (0.25 cm.)	Purulia	30.7
Shallow (25.50 cm.)	Parts of Darjelling, Purulia, Midnapore, Bankura.	318.4
Moderately Shallow (50.75 cm.)	Parts of Darjelling, Midnapore, Purulia, Bankura, Burdwan, Birbhum	125.2
	Total :	**474.3**

Soils under Limiting Drainage Classes

Class	Distribution	Area (.000 ha.)
Very Poorly Drained	Parts of Midnapore, Hooghly, 24-Parganas (S)	173.4
Poorly drained	Parts of 24-Parganas, Nadia, Murshidabad, Jalpaiguri, Coochbehar, Malda, Midnapore, Howrah, Hooghly.	2453.3
Imperfectly Drained	Parts of Burdwan, Birbhum Howrah, Malda, West Dinajpur, Midnapore & Purulia.	1747.6
Excessively Drained	Parts of Derjeeling, Jalpaiguri, Bankura and Purulia.	64.7
	Total :	**4439**

Soils Under Limiting Erosion Classes

Class	Distribution	Area (.000 ha.)
Severe	Parts of Derjeeling, Purulia, Birbhum, Bankura and Midnapore.	57.4
Moderate	Whole West Bengal excepting 24-Parganas (S & N) Nadia, Howrah & Hooghly.	1303.1
	Total :	**1360.5**

Soils Under Limiting Salinity Classes

Class	Distribution	Area (.000 ha.)
Very Strong	Parts of South 24-Parganas & Purba Midanpore.	241
Strong	Parts of South 24-Parganas and Purba Midanpore.	5.7
Moderate	Parts of South 24-Parganas and Purba Midanpore.	131
	Total :	377.7

Soils Under Limiting Textural Classes

Class	Distribution	Area (.000 ha.)
Sandy	Coastal part of Purba Midnapore.	13.7
Gravely loam	Parts of Darjeeling, Paschim Midnapore, Bankura, Purulia.	488.4
Clay	24-Parganas (S), Purba Midnapore, Nadia, Murshidabad, Burdwan.	1550.7
	Total	**2052.8**

Soils Under Limiting Water Logging Classes

Class	Distribution	Area affected (.000 ha.)
Moderate	Cooch Behar, Jalpaiguri, West Dinajpur, Midnapore, Burdwan, Birbhum, Murshidabad.	448.8
Slight	Darjeeling, Jalpaiguri, Coochbehar, West Dinajpur, Malda , Murshidabad, Birbhum, Midnapore, Hooghly, Burdwan, Nadia, Howrah.	808.3
	Total	**1257.1**

Soils Under Limiting Flooding Classes

Class	Distribution	Area affected (.000 ha.)
Moderate	Parts of Jalpaiguri, Cooch Behar, Uttar Dinajpur, Malda, Murshidabad, Nadia, Burdwan, 24-Parganas, Midnapore.	1043.2
Severe	Parts of Hooghly, Midnapore, Murshidabad, Nadia & 24- Parganas	907.2
	Total	**1950.4**

Source : State Forest Report, W.B. 2011-2012, Govt. of West Bengal

Lesson-5

SOIL SCIENCE

Time 1 hour

Lesson Plan

Objective:

- To know functions of major plant nutrients;
- To know soil nutrients as index of fertility;
- To study methods of soil testing. Backward linkage:
- Soil properties in Lesson 2 and 3 Forward Linkage:
- To show the trainees during tour a soil laboratory and explain with demonstrations, if possible, the methods of testing certain soil parameters.

Training materials required:

- Copy of lesson 5 to be circulated beforehand.

Allocation of Time:

- Functions of major plant nutrients – 10 min
- Soil nutrients as index of soil fertility – 5 min
- Soil testing methods – 35 min
- Discussion/ miscellaneous – 10 min

1. Essential Plant Nutrients

(**Source:** Methods manual – Soil Testing in India, Deptt of Agriculture and Cooperation, Ministry of Agriculture, GoI, Jan 2011)

We have discussed in Lesson 2 the major and micro-nutrients required by the plants for growth. These nutrients – 16 in number – are called essential plant nutrients as they have essential functions in the growth of the plants. We may now discuss briefly the functions of some of the major nutrients.

1.1 Carbon

Plants absorb Carbon dioxide CO_2 directly from atmosphere – CO_2 combines with water in presence of sunlight and produces the primary sugars, such as glucose and fructose (fruit sugar) through a process called photosynthesis.

1.2 Oxygen

Oxygen plays a dominant role in photosynthesis and respiration.

1.3 Hydrogen

Hydrogen readily combines with oxygen to form water and with carbon to form complex chemical organic compounds. When organic compounds either break up in the plant or decompose in the soil or atmosphere, the released hydrogen always combines with oxygen and forms water. Thus, the exchange of hydrogen takes place in either of the synthesis or decomposition (including respiration) processes of organic substance.

1.4 Nitrogen

Nitrogen is an essential ingredient of proteins. Nitrogen is the basic nutrient and makes up 1- 4% of dry weight of plants and it forms chlorophyll, amino acids, proteins, alkaloids and protoplasm. When the plant takes up large quantities of nitrogen from the soil, the colour of the plant changes to dark-green, indicating the increase of chlorophyll in the plant. Since the amount of chlorophyll in the plant determines the carbohydrate synthesis, nitrogen, in a way, may be said to control this activity.

1.4.1 Deficiency Symptom

The nitrogen-deficient plants are light green in colour. **The lower leaves turn yellow and in some crops they quickly start drying up as if suffering from shortage of water.**

1.5 Phosphorus

It is a constituent of the cell nucleus, essential for cell division and the development of meristematic tissues at the growing points. It makes 0.1 to 0.5% of dry weight of the plant. Therefore, plants which cannot absorb adequate quantities of phosphorus from the soil have small root system and leaves, and their growth is stunted. **Phosphorus is particularly helpful in the production of legumes, as it increases the activity of nodular bacteria which fix nitrogen in the soil.**

1.5.1 Deficiency Symptom

Generally the plant is dark-green but the lower leaves may turn yellow and dry up. Growth is stunted and leaves become smaller in size.

1.6 Potassium.

It plays a vital role in the formation or synthesis of amino acids and proteins from ammonium ions which are absorbed from the soil. It is also considered essential in the photosynthetic activity of the leaves. It helps in moving manufactured food, viz., carbohydrates (sugars) and proteins (amino acids), from leaves to roots.

1.6.1 Deficiency Symptom

The margins of leaves turn brownish and dry up. The stem remains slender.

2. Soil Testing

(**Source:** Methods manual – Soil Testing in India, Deptt of Agriculture and Cooperation, Ministry of Agriculture, GoI, Jan 2011)

Soil Testing refers to analysis of soil to characterize and estimate the various properties of the soil. These properties include nutrient or fertility status and properties like texture, structure, pH, Cation Exchange Capacity, water holding capacity, electrical conductivity and parameters for amelioration of chemically deteriorated soils. One of the objectives of soil tests is to sort out the nutrient deficient areas from non-deficient ones.

2.1 Soil nutrient as an index of soil fertility

Generally, the soil testing laboratories **use organic carbon as an index of available N, Olsen's and Bray's method for available P, and neutral normal ammonium acetate for K.** In semiarid tropics, nitrate nitrogen is also used as an index of available N in soil. Available nutrient status in the soils is generally classified into several classes. In West Bengal the classes followed are shown in the following table.

Soil Fertility Level	Organic Carbon (%)	Available P_2O_5 kg/ha	Available K_2O kg/ha
Very high	> 1.0	> 115	> 360
High	0.81-1.0	93-115	301-360
Medium	0.61-0.80	71-92	241-300
Medium Low	0.41-0.60	46-70	181-240
Low	0.21-0.40	23-45	121-180
Very Low	<0.21	<23	<121

(**Source:** Methods manual – Soil Testing in India, Deptt of Agriculture and Cooperation, Ministry of Agriculture, GoI, Jan 2011)

3. Soil Testing procedures

(**Source:** Methods manual – Soil Testing in India, Deptt of Agriculture and Cooperation, Ministry of Agriculture, GoI, Jan 2011)

Procedurally, the soil testing programme can be divided into the following components:

(1) **Setting up of a soil testing laboratory**

(2) **Soil sampling** - The method and procedure for obtaining soil samples vary according to the purpose of sampling. Soils vary from place to place. In view of this, efforts should be made to take the samples in such a way that it is fully representative of the field.

(3) **Analytical methods for estimation of physical properties and available nutrients**

We describe below methods for estimation of some of the soil properties.

3.1 Preparation of soil samples for analysis

3.1.1 Drying of samples

Samples received in the laboratory may be moist. These should be dried in wooden or enamelled trays. Care should be taken to maintain the identity of each sample at all stages of preparation. During drying, the trays can be numbered or a plastic tag could be attached. The soils are allowed to dry in the air.

3.1.2 Post drying care

After drying, the samples are taken to the preparation room which is separate from the main laboratory. Air dried samples are ground with a wooden pestle and mortar so that the soil aggregate are crushed but the soil particles do not break down. After grinding, the soil is screened through a 2 mm sieve. After the sample is passed through the sieve, it must be again mixed thoroughly. The soil samples should be stored in cardboard boxes in wooden drawers. These boxes should be numbered and arranged in rows in the wooden drawers, which are in turn fitted in a cabinet in the soil sample room.

3.2 Estimation of Soil Moisture

Gravimetric method of moisture estimation is most widely used where the soil sample is placed in an oven at 105^{o}C and dried to a constant weight. The difference in weight is considered to be water present in the soil sample.

Apparatus

- Aluminium Moisture Box
- Oven
- Desiccator

Procedure

1. Take 100 g of soil sample in the aluminium moisture box and keep in the oven after removing the lid of the box.
2. The sample is kept at 105°C till it attains a constant weight. It may take 24-36 hours.
3. Cool the sample, first in the switched off oven and then in a desiccator.
4. Take the weight of the cooled moisture box. The loss in weight is equal to moisture contained in 100 g soil sample.

Calculation :

$$\text{Moisture (\%)} = \frac{\text{Loss in weight}}{\text{oven}-\text{dry weight of soil}} = \times 100$$

3.3 Estimation of Water Holding Capacity (WHC)

WHC or the Field capacity (FC) is defined as the amount of water held in the soil after the excess gravitational water has drained away and after the rate of downward movement of water has materially ceased. Stage of field capacity is attained in the field after 48 to 72 hours of saturation. It is the upper limit of plant available soil moisture.

Apparatus

- Polythene sheets
- Spade
- Soil auger
- Moisture boxes/cans
- Balance
- Oven

Procedure

1. Select a uniform plot measuring 5 m x 5 m.
2. Remove weeds, pebbles etc. and make bunds around the plot.
3. Fill sufficient water in the plot to completely saturate the soil.
4. Cover the plot area with a polythene sheet to check evaporation.
5. Take soil sample from the centre of the plot from the desired layer, starting after 24 hours of saturation and determine moisutre content daily till the values of successive days are nearly equal.
6. Record the weight as below:

- Weight of empty moisture box = X
- Weight of moisture box + moist soil = Y
- Weight of moisture box + oven dry soil = Z
- Repeat above on next day and so on till a constant Z value is reached.

Calculation

Moisture content in soil = Y – Z Weight of oven dry soil = Z – X

Percentage of moisture in soil (1st day) = $\frac{Y-Z}{Z-X}$ x 100 = a

Percentage of moisture on succeeding days = a_1, a_2, etc.

Plot the daily readings on a graph paper. The lowest reading is taken as a value of field capacity (FC) or WHC of the soil.

3.4 Estimation of Soil pH

Procedure for estimation of soil pH has been discussed in **Lesson 3**.

3.5 Estimation of Organic Carbon/Organic Matter

Organic matter estimation in the soil can be done by different methods. Loss of weight on ignition can be used as a direct measure of the organic matter contained in the soil. It can also be expressed as the content of organic carbon in the soil. **It is generally assumed that on an average organic matter contains about 58% organic carbon**. Organic matter/organic carbon can also be estimated by volumetric and colorimetric methods. However, the use of potassium dichromate ($K_2Cr_2O_7$) involved in these estimations is considered as a limitation because of its hazardous nature. Soil organic matter content can be used as an index of N availability (potential of a soil to supply N to plants) because the content of N in soil organic matter is relatively constant. We describe only the ignition method.

Loss of weight on ignition Apparatus

- Sieve
- Beaker
- Oven
- Muffle furnace

Procedure :

1. Weigh 5.0 to 10.0 g (to the nearest 0.01 g) sieved (2 mm) soil into an ashing vessel (50 ml beaker or other suitable vessel).
2. Place the ashing vessel with soil into a drying oven set at 105^{o}C and dry for 4 hours. Remove the ashing vessel from the drying oven and place in a dry atmosphere. When cooled, weigh to the nearest 0.01 g. Place the ashing vessel with soil into a muffle furnace and bring the temperature to 400^{o}C. Ash in the furnace for 4 hours. Remove the ashing vessel from the muffle furnace, cool in a dry atmosphere and weigh to the nearest 0.01 g.

Calculation :

Percent organic matter (OM) = $\frac{W_1 - W_2}{W_1} \times 100$

Percent organic C = % OM x 0.58

Where,
W1 is the weight of soil at 105^{o}C and W2 is the weight of soil at 400^{o}C.

3.6 Estimation of Available Phosphorus

Two methods are most commonly used for determination of available phosphorus in soils: Bray's Method No.1 for acidic soils and Olsen's Method for neutral and alkaline soils. In these methods, specific coloured compounds are formed with the addition of appropriate reagents in the solution, the intensity of which is proportionate to the concentration of the element being estimated. The colour intensity is measured spectrophotometrically. In spectrophotometric analysis, light of definite wavelength (not exceeding say 0.1 to 1.0 nm in band width) extending to the ultraviolet region of the spectrum constitutes the light source. The photoelectric cells in spectrophotometer measure the light transmitted by the solution.

3.6.1 A spectrophotometer, as its name implies, is really two instruments in one cabinet – a spectrometer and a photometer. A spectrometer is a device for producing coloured light of any selected colour (or wavelength) and, when employed as part of a spectrophotometer, is usually termed as monochromator and is generally calibrated in wavelengths (nm). A photometer is a device for measuring the intensity of the light, and when incorporated in a spectrophotometer is used to measure the intensity of the monochromatic beam produced by the associated monochromator. Generally, the photometric measurement is made first with a reference liquid and then with a coloured sample contained in similar cells interposed in the light beam: the ratio of the two intensity measurements being a measure of the opacity of the sample at the wavelength of the test. We describe below the Bray's Method No.1.

3.6.1 Bray's method No. 1 (Bray and Kurtz, 1945) for acid soils Apparatus

- Spectrophotometer
- Pipette - 2 ml, 5 ml, 10 ml and 20 ml
- Beakers/flasks - 25 ml, 50 ml, 100 ml and 500 ml

Reagents

- Bray Extractant No 1 (0.03M NH4F in 0.025M HCL): Dissolve 2.22 g of NH4F in 200 ml of distilled water, filter, and add to the filtrate 1.8 litres of water containing 4 ml of concentrated HCl, make up the volume to 2 litres with distilled water.
- Molybdate reagent: Dissolve 1.50 g $(NH_4)_2MoO_4$ in 300 ml distilled water. Add the solution to 350 ml of 10M HCl solution gradually with stirring. Dilute to 1 litre with distilled water.
- Stannous chloride solution (Stock Solution): Dissolve 10 g $SnCl_2$ $2H_2O$ in 25 ml of concentrated HCl. Add a piece of pure metallic tin and store the solution in a glass stoppered bottle.
- Stannous chloride solution (Working Solution): Dilute 1 ml of the stock solution of stannous chloride to 66.0 ml with distilled water just before use. Prepare fresh dilute solution every working day.

Procedure

1. **Preparation of the Standard Curve**: Dissolve 0.1916 g of pure dry KH_2PO_4 in 1 litre of distilled water. This solution contains 0.10 mg P_2O_5 /ml. Preserve this as a stock standard solution of phosphate. Take 10 ml of this solution and dilute it to 1 litre with distilled water. This solution contains 1 ìg P_2O_5/ml (0.001 mg P_2O_5/ml). Take 1, 2, 4, 6 and 10 ml of this solution in separate 25 ml flasks. Add to each, 5 ml of the extractant solution, 5 ml of the molybdate reagent and dilute with distilled water to about 20 ml. Add 1 ml dilute SnCl2 solution, shake again and dilute to the 25 ml mark. After 10 minutes, read the blue colour of the solution on the spectrophotometer at 660 nm wavelength. Plot the absorbance reading against ìg P_2O_5 and join the points.

2. **Extraction**: Add 50 ml of the Bray's extractant No. 1 to the 100 ml conical flask containing 5 g soil sample. Shake for 5 minutes and filter.

3. **Development of colour**: Take 5 ml of the filtered soil extract with a bulb pipette in a 25 ml measuring flask; deliver 5 ml of the molybdate reagent with an automatic pipette, dilute to about 20 ml with distilled water, shake and add 1 ml of the dilute $SnCl_2$ solution with a bulb pipette. Fill to the 25 ml mark and shake thoroughly. Read the blue colour after 10 minutes on the spectrophotometer at 660 nm wavelength after setting the instrument to zero with the blank prepared similarly but without the soil.

Calculation

$$P\ (kg / ha) = \frac{A}{1000000} \times \frac{50}{5} \times \frac{2000000}{5}$$

Where,

Weight of the soil taken = 5 g Volume of the extract = 50 ml

Volume of the extract taken for estimation = 5 ml

Volume made for estimation (dilution = 5 times) = 25 ml

Amount of P observed in the sample on the standard curve = A (ìg).

Wt. of 1 ha of soil upto a depth of 22 cm is taken as 2 million kg.

Standard Curve

As an example, the standard curve prepared by Motsara and Roy (2008) for estimation of available P by Bray's method while establishing a soil testing laboratory in DPR Korea is given in the Figure 5.1.

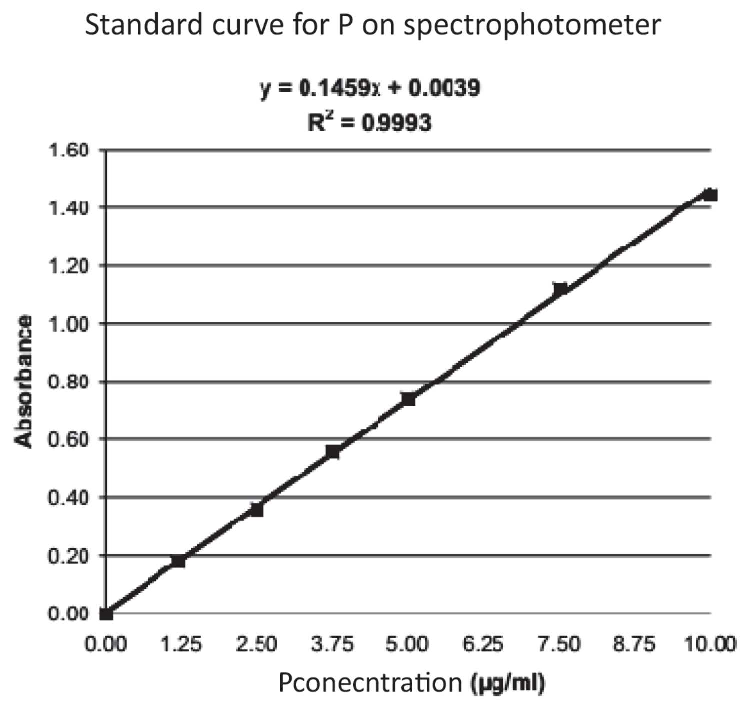

Fig.5.1

(Source: Methods manual – Soil Testing in India, Deptt of Agriculture and Cooperation, Ministry of Agriculture, GoI, Jan 2011)

3.7 Estimation of Available Potassium

Flame photometeric method (Toth and Prince, 1949)

Potassium present in the soil is extracted with neutral ammonium acetate of 1 molarity. This is considered as plant available K in the soils. It is estimated with the help of flame photometer. This is a well-accepted method.

Apparatus:

- Multiple Dispenser or automatic pipette – 25 ml
- Flasks and beakers - 100 ml
- Flame Photometer

Reagents:

- Molar neutral ammonium acetate solution: Dissolve 77 g of ammonium acetate ($NH_4C_2H_3O_2$) in 1 litre of water. Check the pH with bromothymol blue or with a pH meter. If not neutral, add either ammonium hydroxide or acetic acid as per the need to neutralize it to pH 7.0.
- Standard potassium solution: Dissolve 1.908 g pure KCl in 1 litre of distilled water. This solution contains 1 mg K/ml . Take 100 ml of this solution and dilute to 1 litre with ammonium acetate solution. This gives 0.1 mg K/ml as stock solution.
- Working potassium standard solutions: Take 0, 5, 10, 15 and 20 ml of the stock solution separately and dilute each to 100 ml with the M ammonium acetate solution. These solutions contain 0, 5, 10, 15 and 20 ìg K/ml, respectively.

Procedure:

1. **Preparation of the Standard Curve**: Set up the flame photometer by atomizing 0 and 20 ìg K/ml solutions alternatively to 0 and 100 reading. Atomize intermediate working standard solutions and record the readings. Plot these readings against the respective potassium contents and connect the points with a straight line to obtain a standard curve.
2. **Extraction**: Add 25 ml of the ammonium acetate extractant to conical flask fixed in a wooden rack containing 5 g soil sample. Shake for 5 minutes and filter.
3. Determine potash in the filtrate with the flame photometer

Calculation :

$$K(kg / ha) = A \times \frac{25}{5} \times \frac{2000000}{1000000} = 10A$$

A = content of K (ìg) in the sample, as read from the standard curve: Weight of 1 ha of soil upto a plough depth of 22 cm is approx. 2 million kg.

Standard Curve:

While setting up the soil testing laboratory at DPR Korea, following standard curve (Figure 5.2) was prepared by Motsara and Roy (2008) for estimation of K on flame photometer following the above method.

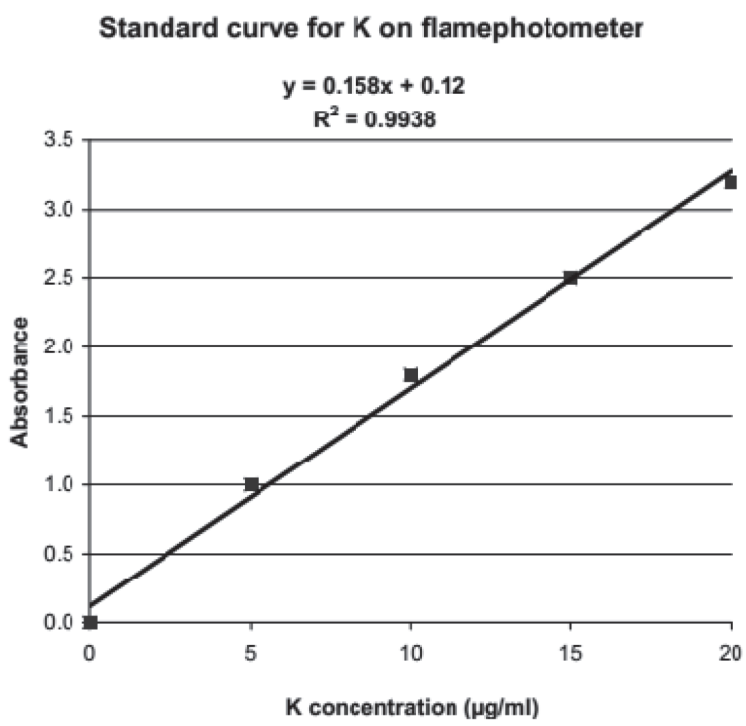

Fig.5.2

(Source: Methods manual – Soil Testing in India, Deptt of Agriculture and Cooperation, Ministry of Agriculture, GoI, Jan 2011)

Reference materials:

(1) Introductory Soil Science by S S Negi (Bishen Singh Mahendra Pal Singh Dehradun) Methods manual – Soil Testing in India, Deptt of Agriculture and Cooperation, Ministry of Agriculture, GoI, Jan 2011