

Soil and Plant Analysis



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Soil and Plant Analysis

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Lesson- 1

Soil Sampling - importance, methods of sampling and processing of soil samples

Introduction

- The objective of soil sampling is to obtain reliable information about a particular soil.
- The value of laboratory data in soil studies largely depends on effective sampling.
- Soil sampling is one of the most important aspects in the determination of the properties of the soil.
- Care in preparation and analysis can overcome the damages of careless or inappropriate sampling in the field (Bates, 1993).
- Errors arising from sampling are mainly related to spatial variability of the soil.
- While keeping in mind financial constraints, sampling procedures should be adopted properly to minimize the influence of spatial variability and to maximize the accuracy of mean plot values for the measured soil variables.
- The obtained soil data should be representative for the whole observation plot, taking into consideration the spatial variability of the soil within the plot.

Importance of Soil Sampling

- Soil sampling and testing are done to provide an estimate of the capacity of the soil to supply adequate amount of nutrients to meet the needs of growing crops and information to its nature and problem.
- Traditionally, the goal of soil sampling is to develop a representative estimate of a field.
- A few grams of soil are actually used for the laboratory analysis.

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- That small amount must represent the entire area for which the recommendation is to be made.
- The samples should be collected in such a way that it would represent the area for which recommendation is to be made.

Sampling Units

- Each sample should represent 2 ½ acres or less for best characterization of the variability within the field, to serve as a guide for variable-rate application of plant nutrients.
- Where field variability is low, larger sample areas are acceptable; where variability is high; more samples are needed to adequately represent the field. Each field is to be treated as a separate sampling unit.
- Further, fields with varying soil types, slope and past management practices such as fertilization, liming and cropping pattern need to be treated as separate sampling units.

Sampling Depth

Sampling depth should be determined to represent the root zone that the plant will draw from, but should also be consistent with the sampling depth used in developing the calibration data set to be used for interpreting the soil tests.

Prescribed depth of soil sampling

Field crops	15-20 cm
Deep rooted crops	30-60 cm (Sampling at different depths or layers is ideal)
Forage or pasture crops	8-10 cm
For immobile nutrients (P, K, Ca and Mg)	Sampling at tillage depth
Nitrate, Sulfate	60 cm (when the biological activity is low)
Saline alkali soils	Salt crust should be sampled separately and the depth of sampling should be recorded

When to sample?

- Fields used for crop production are best sampled at any time after harvest and before planting.
- Collect samples after harvest, usually three to six months before planting or three months of after fertilizer application.
- Doing so gives time to plan a liming and fertilization programme before the busy planting season.
- Sample whenever subnormal growth or plant discoloration occurs.
- For coastal soils, collect samples every two years or test one half of the land every year.
- Sandy soils lose nutrients quickly and become acidic when nitrogen is added.
- For mountain or variegated soils, collect samples every three years or test one third of land every year.
- Silt and clay loam soils do not lose nutrients as quickly as sandy soils. Do not sample immediately after fertilizer has been applied.
- Soils should be tested as often as necessary to determine the influence of cultural practices and crop production on soil chemical properties. Nitrogen results are usually the most variable.
- So take samples as close to planting time as possible. Nitrate -N concentrations should be determined on annual basis.
- Phosphorus and potassium should be tested every three to four years. To account for seasonal variations, soil samples should be collected at approximately same time each year.

Do Not Sample

- Dead or back furrows
- Fencerows, old or new
- Old roadbeds, or near limestone gravel roads
- Terrace channels
- Wind breaks or snow fence lines
- Turn-rows
- Spill areas

Sampling points

- Uniform fields can be sampled in a simple random, stratified random or in a systematic pattern.
- The soil test result from these sampling plans, provides an estimate of the entire population of possible soil test results.
- As the number of cores increases, the error or chance of inaccurate estimate of the average soil test value decreases. With a simple random system, each soil core is selected separately, randomly of previously drawn units.
- A stratified random sample is taken from a field that has been divided into several subunits or quadrants from which simple cores are obtained.
- The systematic sample is a further progression is an attempt to ensure complete field coverage, similar to the change from the simple random to the stratified random.
- Sample cores are taken at regularly spaced intervals in all directions.

Materials required

Spade

1. Khurpi
2. Auger (screw or pos-thole type)
3. Core sampler

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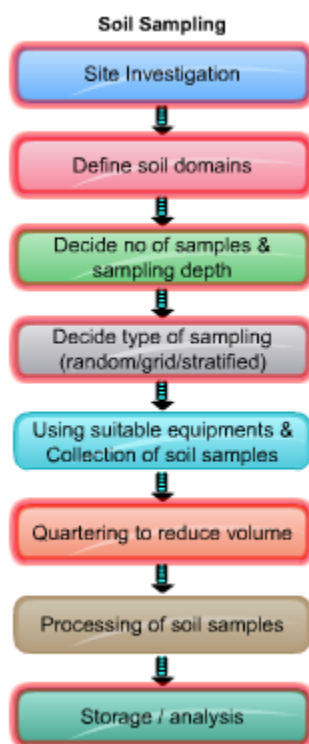
4. Soil testing tube (for wet soil)
5. Sampling bags
6. Plastic basin or bucket
7. Plastic sheet and
8. Information sheet etc.

Collection of soil samples from the field

- Normally each field may be treated as a sampling unit. But two or more fields, which are similar in appearance, production and past-management practices may be grouped together into a single sampling unit.
- Samples should be collected separately from areas, which differ in soil colour or past-management practices such as liming, fertilization, cropping pattern etc.
- During collection of soil, dead furrows, old manure or lime piles, wet spots, areas near trees, manure pits, compost pits, near field bunds and irrigation channels must be avoided.
- The sampling should be done in a zigzag pattern across the field to get homogeneity. A wise collecting agent is one who collects samples in the presence of the owner or cultivator of the land who is the best judge in deciding which area of his farm should be sampled separately.
- Scrap away the surface litter and insert the sampling auger to plough depth (15 cm).
- Take at least 15 samples randomly distributed over each area and put them in a clean bucket.
- If a sampling auger is not available make a 'V' or 'U' shaped cut to a depth of 15 cm or to a required depth using a spade and remove 1.0 to 1.5 cm thick slice of soil from top to bottom of the exposed face of the 'V' or 'U' shaped cut and put in a clean bucket or basin and in similar manner collect the soil sample from all the spots.
- Thoroughly mix the soil samples taken from 15 or more spots of each area. Remove foreign bodies such as plant roots, stubbles, leaves, glass pieces, pebbles, stones or gravels. By quartering technique, discard all but $\frac{1}{2}$ to 1 kg soil.
- Quartering technique is done by dividing the thoroughly mixed soil into four equal parts and discarding two opposite quarters.
- Remix the remaining two quarters and again divide into four equal parts and reject the opposite two.

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- Repeat this procedure until about ½ to 1 kg of soil is left. Instead of quartering, compartmentalization method can be followed.
- For this, spread the soil on a clean hard surface and mark lines from both the sides and create number of compartments.
- Take a little quantity of soil from each compartment and put into a clean container.
- Repeat the process of collection until the required quantity is collected.
- Store the soil in a clean cloth bag or container with proper labeling for further analysis.



Collection of soil samples from a profile

- After the profile has been exposed, clean one face of the pit carefully with a spade and note the succession and depth of each horizon.
- Prick the surface with a knife or edge of the spade to show up structure, colour and compactness.
- Describe the profile as per the standard terminologies.
- Use the Munsell colour chart for noting the colour and find out the texture by feel method.
- Collect samples from each horizon by holding a large basin at the bottom limit of the horizon while the soil above is loosened by a khurpi. Mix sample and transfer to a bag after labelling.

Preparation of soil sample for analysis

Steps involved in the preparation and processing of soil sample are Drying Grinding

- Sieving
- Storing

The soil sample received at the laboratory is air-dried in shade and spread on a sheet of paper after breaking large lumps, if present, with a wooden mallet. It is further ground by pounding with a wooden mallet in such a way that the aggregate particles are broken down to ultimate soil particles. The soil thus prepared is sieved through a sieve with round holes, 2 mm in diameter. The material on the sieve is again ground and sieved till all aggregate particles are fine enough to pass through and only stones and organic residues remain on the sieve. For micronutrients analysis nylon sieve should be used. Mix well the 'fine soil' got by sieving and store in a suitable bottle or container with one label on the outside and another inside the container.

Objectives of soil testing

1. Evaluation of fertility status of soil
2. Estimation of the available nutrients status of soil
3. Evaluation of the suitability of soil for laying garden
4. Determination of acidity, salinity and alkalinity problems and
5. Recommendation of the required amount of fertilizers, lime or gypsum based on soil test value.

For determination of organic carbon, powder and sieve the soil through 0.2 mm sieve. For micronutrient analysis, iron, brass, copper and zinc containers must be avoided for collection and storage of soil samples and plastic implements and sieve must be used for sieving.

Sub sampling for analysis

- Empty the soil in the bottle on a clean thick sheet of paper and spread evenly with a sampling knife.
- Heap the soil into a cone by raising the four ends of the paper and again mix it well and spread evenly on the paper as before.
- Repeat the process 3 or 4 times to ensure uniformity and then spread evenly on the paper again finally.
- Now divide the soil into four equal quarters and take a small quantity of soil from various points in each quarter to get a representative sample for analysis.



Lesson- 2
Soil Structure, Types of Soil Structure and Aggregate Analysis

Soil structure – Definition

“The arrangement and organization of primary and secondary particles in a soil mass is known as soil structure”.

(Or)

“The grouping and arrangement of soil particles (Sand, silt and clays) is known as soil structure.

Significance of soil structure

- Other soil properties like water movement, heat transfer, aeration, and porosity are influenced by structure.
- The important physical changes imposed by the farmer in ploughing, cultivating, draining, liming, and manuring his land are structural.
- Structure can be modified by cultivation and tillage operations while texture is an inherent property of soil and cannot be modified within short period of time.
- Soil structure controls the amount of water and air present in soil. Plant roots and germinating seeds require sufficient air and oxygen for respiration.
- Microbial activities also depend upon the supply of water and air in the soil.

Formation of soil structure

- Soil particles are present as single individual grains and as aggregates i.e. group of particles bound together into granules.
- These granules are known as secondary particles.

Soil and Plant Analysis

- Particles in sandy and silty soils are present as single individual grains while in loamy and clayey soils they are present in granulated condition.
- Most soils are mixtures of individual particles and aggregates.
- Soils predominated with individual particles are said to be structure-less, while those with higher proportion of aggregates would have different forms of structure.

Mechanism of aggregate formation

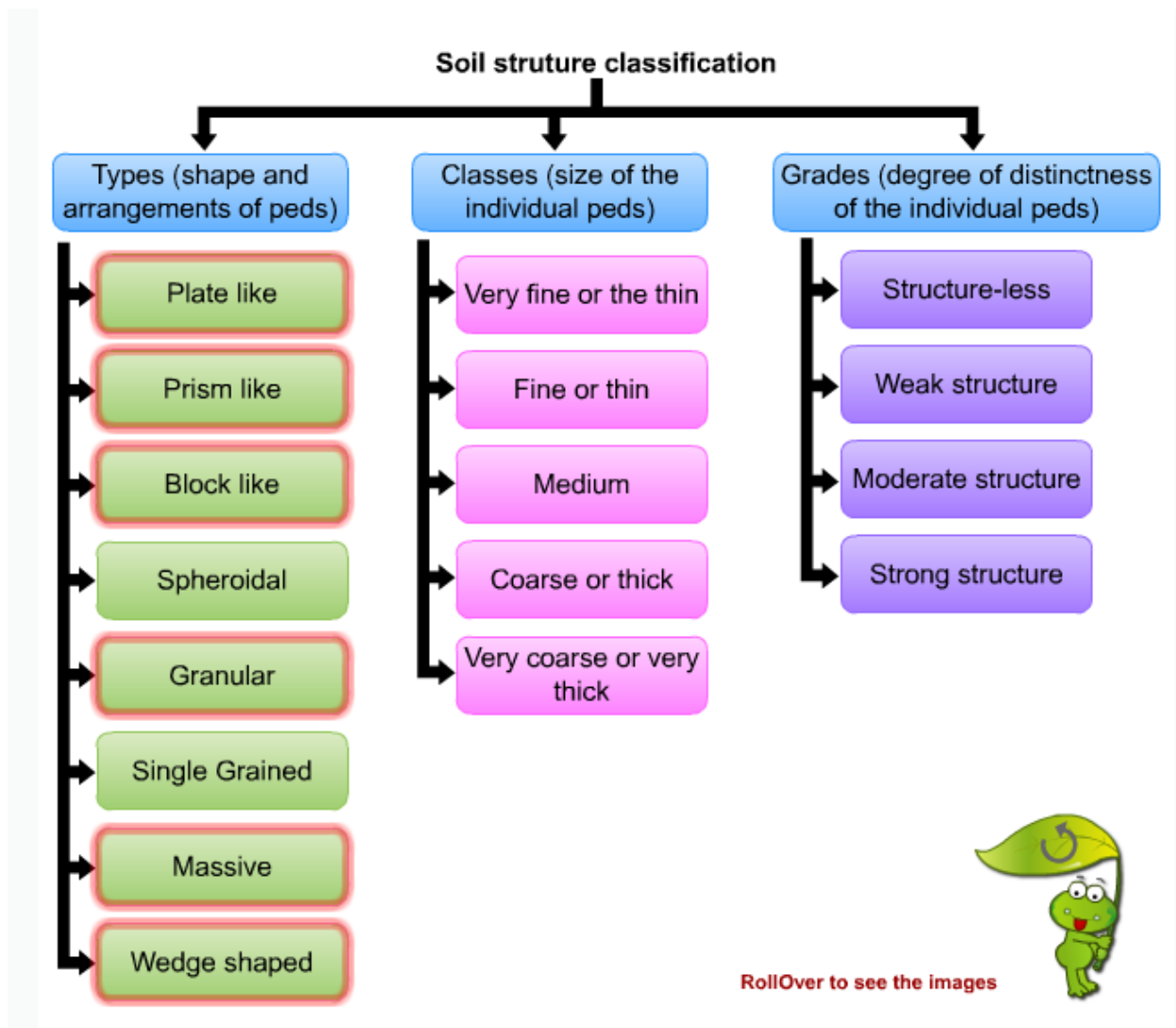
- The bonding of the soil particles into structural unit is called as the genesis of soil structure.
- The bonding between individual particles in the structural units is generally considered to be stronger than the structural units themselves.
- In aggregate formation, a number of primary particles such as sand, silt and clay are brought together by the cementing or binding effect of soil colloids.
- The cementing materials taking part in aggregate formation are colloidal clay, iron and aluminium hydroxides and decomposing organic matter.
- Whatever may be the cementing material, it is ultimately the dehydration of colloidal matter accompanied with pressure that completes the process of aggregation.

Classification

Soil structure is the way soil particles aggregate together into what are called peds. Peds come in a variety of shapes depending on the texture, composition, and environment.

The primary particles - sand, silt and clay - usually occur grouped together in the form of aggregates. Natural aggregates are called peds whereas clod is an artificially formed (due to ploughing, digging etc.) soil mass. Structure is studied in the field under natural conditions and it is described under three categories.

1. Type - Shape or form and arrangement pattern of peds
2. Class - Size of Peds
3. Grade - Degree of distinctness of peds



Types of Structure

There are four principal forms of soil structure

1) Plate-like (Platy)

- In this type, the aggregates are arranged in relatively thin horizontal plates or leaflets.
- The horizontal axis or dimensions are larger than the vertical axis.
- When the units/ layers are thick they are called platy
- When they are thin then it is laminar.

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- Platy structure is most noticeable in the surface layers of virgin soils but may be present in the subsoil also.
- This type is inherited from the parent material, especially by the action of water or ice.

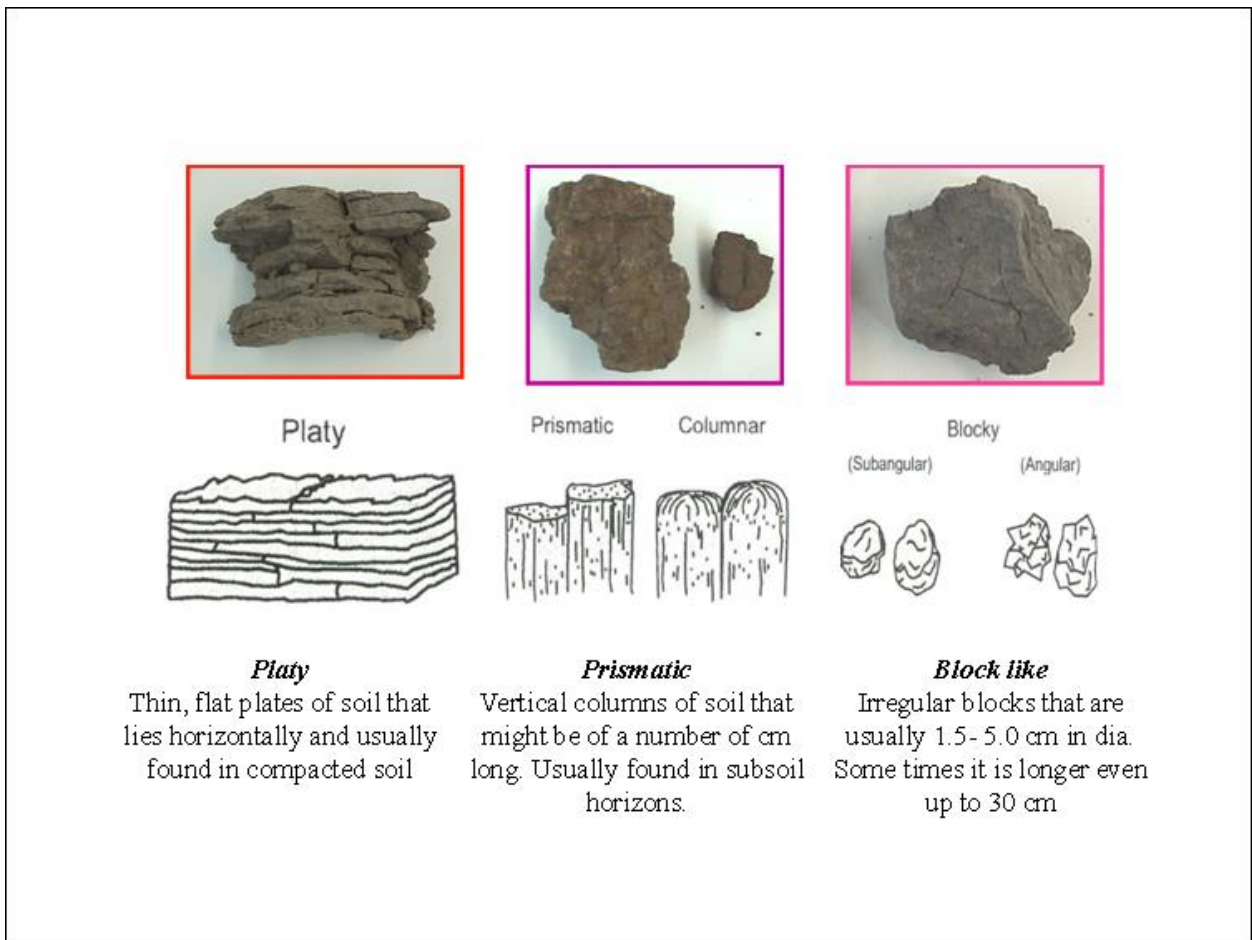
2) Prism-like

- The vertical axis is more developed than horizontal, giving a pillar-like shape.
- Vary in length from 1- 10 cm.
- Commonly occur in sub soil horizons of arid and semi arid regions.
- When the tops are rounded, the structure is termed as columnar and when the tops are

flat / plane and clear cut, it is called as prismatic structure.

3) Block-like

- All three dimensions are of almost the same size.
- Irregularly six faced with their three dimensions more or less equal.
- When the faces are flat and distinct and the edges are sharp angular, the structure is named as angular blocky.
- When the faces and edges are mainly rounded it is called sub angular blocky.
- These types usually are confined to the sub soil and their characteristics have much to do with soil drainage, aeration and root penetration.



4) Spheroidal (Sphere-like)

- All rounded aggregates (peds) may be placed in this category.
- Not exceeding an inch (2.5 inch) in diameter.
- These rounded aggregates are usually loosely arranged and can be readily separated.
- When wetted, the intervening spaces generally are not closed so readily by swelling as may be the case with a blocky structural condition.
- Therefore in sphere-like structure, infiltration, percolation and aeration are not affected by wetting of the soil.
- The aggregates of this group are usually termed as granular when they are relatively less porous.

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- When the granules are very porous, they are termed as crumbs.
- This is specific to the surface soil, particularly, high in organic matter/ grass-land soils.

5) Granular

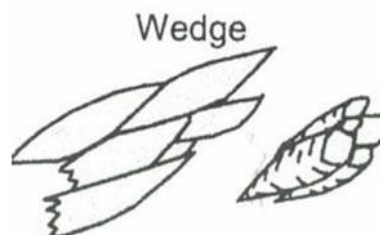
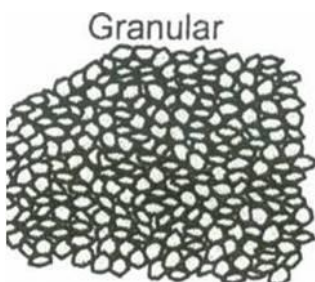
- Resembles biscuit crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.

6) Single Grained

- Soil is broken into individual particles that don't stick together. Always accompanies a loose consistency. Commonly found in sandy soils.

7) Massive

- Soil has no visible structure, is hard to break apart and appears in very large clods.



8) Wedge structure

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- Elliptical Interlocking lenses that terminate in acute angles, bounded by slickensides. This structure is not limited to Vertic Martials or Vertisols. Also present in soil with high clay content and with expanding clays.

Classes of Structure

Each primary structural type of soil is differentiated into 5 size classes depending upon the size of the individual peds.

The terms commonly used for the size classes are

1. Very fine or very thin
2. Fine or thin
3. Medium
4. Coarse or thick
5. Very Coarse or very thick

The terms thin and thick are used for platy types, while the terms fine and coarse are used for other structural types.

Grades of structure

Grades indicate the degree of distinctness of the individual peds. It is determined by the stability of the aggregates. Grade of structure is influenced by the moisture content of the soil. Grade also depends on organic matter content, texture etc. Four terms commonly used to describe the grade of soil structure are:

Structure-less

- There is no noticeable aggregation, such as conditions exhibited by loose sand.

Weak structure

- Poorly formed, indistinct formation of peds, which are not durable and much UN-aggregated material.

Moderate structure

- Moderately well-developed peds, which are fairly durable and distinct.
- Strong structure: Very well formed peds, which are quite durable and distinct.

Structure naming

For naming a soil structure the sequence followed is grade, class and type; for example strong coarse angular blocky, moderate thin platy, weak fine prismatic.

Factors affecting soil structure

The development of structure in arable soil depends on the following factors:

1.Climate: Climate has considerable influence on the degree of aggregation as well as on the type of structure. In arid regions, there is very little aggregation of primary particles. In semi-arid regions, the degree of aggregation is greater.

2.Organic matter: Organic matter improves the structure of a sandy soil as well as of a clayey soil. In case of a sandy soil, the sticky and slimy material produced by the decomposing organic matter and the associated microorganisms cement the sand particles together to form aggregates. In case of clayey soil, it modifies the properties of clay by reducing its cohesiveness. This helps making clay more crumby.

3.Tillage: Cultivation implements break down the large clods into smaller fragments and aggregates. For obtaining good granular and crumby structure, optimum moisture content in the soil is necessary. If the moisture content is high it will form large clods on drying. If it is low,

some of the existing aggregates will be broken down.

4.Plants, roots and residues:

- Excretion of gelatinous organic compounds and exudates from roots serve as a link
- Root hairs make soil particles to cling together. Grass and cereal roots Vs other roots
- Pressure exerted by the roots also hold the particles together
- Dehydration of soil leads to shrinkage forming cracks leading to aggregation
- Plant tops and residues, shade the soil and prevent it from extreme and sudden temperature and moisture changes and also from rain drop impedance.
- Plant residues also serve as a food to microbes which are the prime aggregate builders.

5.Animals : Among the soil fauna, small animals like earthworms, moles and insects that burrow in the soil are the chief agents that take part in the aggregation of finer particles.

6.Microbes: Algae, fungi, actinomycetes and bacteria keep the soil particles together. Fungi and actinomycetes exert mechanical binding by mycelia. Cementation by the products of decomposition and materials synthesized by bacteria encourages aggregate formation.

7.Fertilizers: Fertilizer like Sodium nitrate destroys granulation by reducing the stability of aggregates. A few fertilizers like CAN help in the development of good structures.

8.Wetting and drying: When a dry soil is wetted, the soil colloids swell on absorbing water. On drying, shrinkage produces strains in the soil mass gives rise to cracks, which break it up into clods and granules of various sizes.

9.Exchangeable cations: Ca, Mg --> Flocculating leading to good structure H, Na --> Deflocculating leading to poor structure

10.Inorganic cements: CaCO₃ and sesquioxides

11.Clay and water

Effect of soil structure on other physical properties

Porosity: Porosity of a soil is easily changed. In plate-like structure, pore-spaces are less whereas in crumby structure pore-spaces are more.

Temperature: Crumby structure provides good aeration and percolation of water in the soil. Thus these characteristics help in keeping optimum temperature in comparison to plate-like structure.

Density: Bulk density varies with the total pore-space present in the soil. Structure chiefly influences pore-spaces. Platy structure with less total pore spaces has high bulk density whereas crumby structure with more total pore spaces has low bulk density.

Consistence: Consistence of soil also depends on structure. Plate-like structure exhibits strong plasticity.

Colour: Bluish and greenish colors of soil are generally due to poor drainage of soil. Platy structure normally hinders free drainage whereas sphere like structure (granular and crumby) helps in drainage.

Air and water: Structure controls the amount of water and air present in the soil. Not only the amounts of water and air are dependent on soil structure, but their movement and circulation are also controlled by the soil structure. Crumby and granular structures provide optimum infiltration, water holding capacity, aeration and drainage.

They also provide good habitat for microorganisms and supply nutrients. Structure controls runoff and erosion.

Improvement of Soil Structure

- Addition of lime to acidic soils improves their structure because lime stimulates growth of microbes (responsible for the improvement of soil structure). Addition of calcium nitrate also improves soil structure.
- Addition of large doses of partially decomposed organic manures like FYM, compost and green manure crops greatly improves soil structure.
- Surface of land covered with waste organic material like grasses, leaves, straw, etc. (mulches) keep the soil surface moist and cool so that microbes can multiply rapidly and improve soil structure.
- Mulches also protect the soil surface from the beating action of the raindrop that may destroy the soil structure to a great extent.
- There are some synthetic soil conditioners like polyacrylic acid (PAA), polyacrylonitrile (PAN) and vinyl acetate maleic acid copolymer (VAMA). But they are very costly.

Evaluation of soil structure

Soil structure can be evaluated by determining the extent of aggregates, the stability of the aggregates and the nature of the pore-space.

All these characteristics change with tillage practices and cropping systems. The volume

Aggregate analysis

There are generally three techniques that can be followed for the aggregate analysis –

(i) wet and dry sieving

(ii) elutriation and

(iii) sedimentation Direct dry sieving of soils in the field is used to evaluate the distribution of clods and aggregates.

Soil and Plant Analysis

Dry sieving of aggregates gives an important index for characterizing the susceptibility of soil to wind erosion. In the wet sieving technique, the soil is slowly wetted by capillarity for 30 minutes and is then transformed onto a nest of sieves immersed in water. The sieves are slowly raised and lowered in the water for 30 minutes. The weight of soil on each sieve is then determined. Elutriation may be used for the separation of aggregates with diameters between 1 and 0.02 mm. Sedimentation methods have been used to determine the aggregate distribution in the finer fractions that cannot be separated by sieving. They are limited to aggregate sizes less than 1 mm. There are generally two limitations of sedimentation method : varying density of particles and possibility of flocculation during sedimentation because of the downward motion of the large aggregates.



Lesson- 3

Theories and Concepts of Soil Moisture Estimation – Gravimetric, Tensiometer, Gypsum Block, Neutron Probe and Pressure Plate Methods

Soil water potential

An understanding of soil water potential is useful before moving to soil water measurements.

Soil water potential

The retention and movement of water in soils, its uptake and translocation in plants and its loss to the atmosphere are all energy related phenomenon. The more strongly water is held in the soil the greater is the heat (energy) required to remove it. In other words, if water is to be removed from a moist soil, work has to be done against adsorptive forces. Conversely, when water is adsorbed by the soil, a negative amount of work is done. The movement is from a zone where the free energy of water is high (standing water table) to one where the free energy is low (a dry soil). This is called soil water energy concept.

Free energy of soil solids for water is affected by

- i) Matric (solid) force i.e., the attraction of the soil solids for water (adsorption) which markedly reduces the free energy (movement) of the adsorbed water molecules.
- ii) Osmotic force i.e., the attraction of ions and other solutes for water to reduce the free energy of the soil solution.

Matric and Osmotic potentials are negative and reduce the free energy level of the soil water. These negative potentials are referred to as suction or tension.

- iii) Force of gravity: This acts on soil water and the attraction is towards the earth's center, which tends to pull the water downward. This force is always positive.

The difference between the energy states of soil water and pure free water is known as soil water potential. Total water potential (P_t) Ψ_t is the sum of the contributions of gravitational potential (P_g) Ψ_g , matric potential (P_m) Ψ_m and the Osmotic potential or solute potential (P_o) Ψ_o .

$$P_t \Psi_t = P_g \Psi_g + P_m \Psi_m + P_o \Psi_o$$

Potential represents the difference in free energy levels of pure water and of soil water.

The soil water is affected by the force of gravity, presence of soil solid (matric) and of solutes.

Soil Moisture Constants

Earlier classification divided soil water into gravitational, capillary and hygroscopic water. The hygroscopic and capillary waters are in equilibrium with the soil under given conditions. The hygroscopic coefficient and the maximum capillary capacity are the two equilibrium points when the soil contains the maximum amount of hygroscopic and capillary waters, respectively. The amount of water that a soil contains at each of these equilibrium points is known as soil moisture constant.

The soil moisture constant, therefore, represents definite soil moisture relationship and retention of soil moisture in the field.

The three classes of water (gravitational, capillary and hygroscopic) are however very broad and do not represent accurately the soil - water relationships that exist under field conditions.

Though the maximum capillary capacity represents the maximum amount of capillary water that a soil holds, the whole of capillary water is not available for the use of the plants. The plants can not utilize a part of it, at its lower limit approaching the hygroscopic coefficient. Similarly, a part of the capillary water at its upper limit is also not available for the use of plants. Hence, two more soil constants; viz., field capacity and wilting coefficient have been introduced to express the soil-plant-water relationships as found to exist under field conditions.

1. Field capacity: It is the capacity of the soil to retain water against the downward pull of the force of gravity. At this stage, only micropores or capillary pores are filled with water and plants absorb water for their use. At field capacity, water is held with a force of 1/3 atmosphere. Water at field capacity is readily available to plants and microorganisms.

2. Wilting coefficient: The stage at which plants start wilting for want of water is termed the Wilting Point and the percentage amount of water held by the soil at this stage is known as the Wilting Coefficient. It represents the point at which the soil is unable to supply water to the plant. Water at wilting coefficient is held with a force of 15 atmospheres.

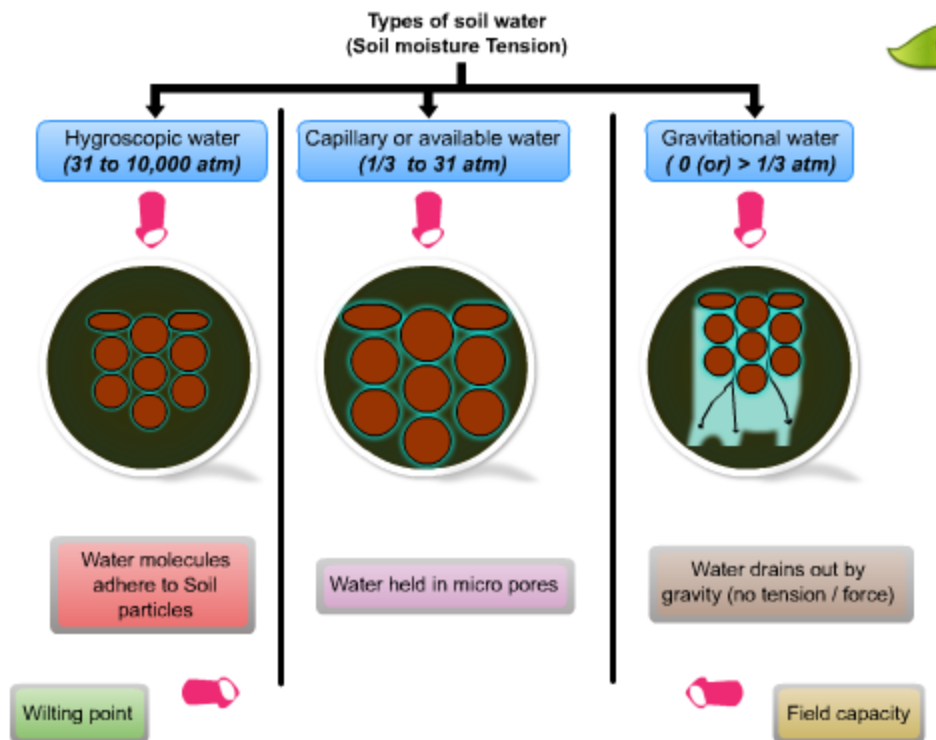
3. Hygroscopic coefficient: The hygroscopic coefficient is the maximum amount of hygroscopic water absorbed by 100 g of dry soil under standard conditions of humidity (50% relative humidity) and temperature (15°C). This tension is equal to a force of 31 atmospheres. Water at this tension is not available to plant but may be available to microorganisms.

4. Available water capacity: The amount of water required to apply to a soil at the wilting point to reach the field capacity is called the "available" water. The water supplying power of soils is related to the amount of available water a soil can hold. The available water is the difference in the amount of water at Field Capacity (0.3 bar) and the amount of water at the Permanent Wilting Point (15 bars).

5. Maximum water holding capacity: It is also known as maximum retentive capacity. It is the amount of moisture in a soil when its pore spaces, both micro and macro-capillary, are completely filled with water. It is a rough measure of total pore space of soil. Soil moisture tension is very low between 1/100th to 1/1000th of an atmosphere or pF 1 to 0. Summary of the soil moisture constants, type of water and force with which it is held, is given in following table.

Soil moisture constants and range of tension and pF

S.No.	Moisture class	Tension (atm/bar)	pF
1	Chemically combined	Very high	---
2	Water vapour	Held at saturation point in the soil air	---
3	Hygroscopic	31 to 10,000	4.50 to 7.00
4	Hygroscopic coefficient	31	4.50
5	Wilting point	15	4.20
6	Capillary or available water	1/3 to -31	2.54 to 4.50
	Moisture equivalent	1/3 to 1	2.70 to 3.00
	Field capacity	1/3	2.54
	Sticky point	1/3 (more or less)	2.54
	Gravitational	Zero or less than -1/3	<2.54
	Maximum water holding capacity	Almost zero	---



Soil Moisture measurement

There are fundamentally two ways of soil moisture measurement. They are

- i) Direct measurement of moisture content
- ii) Measurement of soil moisture potential (tension or suction)

1. Gravimetric method

This consists of obtaining a moist sample, drying it in an oven at 105°C until it loses no more weight and then determining the percentage of moisture. The gravimetric method is time-consuming and involves laborious processes of sampling, weighing and drying in the laboratory.

Advantages

- Ensures accurate measurements
- Not dependent on salinity and soil type
- Easy to calculate

Disadvantages

- Destructive test
- Time-consuming
- Inapplicable to automatic control
- Must know dry bulk density and to transform data to volume moisture content

2. Electrical conductivity method

This method is based upon the changes in electrical conductivity with changes in soil moisture. Gypsum blocks inside of which two electrodes at a definite distance apart are used in this method. These blocks require previous calibration for uniformity. The blocks are buried in the soil at desired depths and the conductivity across the electrodes measured with a modified Wheatstone bridge. These electrical measurements are affected by salt concentration in the soil solution and are not very helpful in soils with high salt contents.

Advantages

- Inexpensive

Disadvantages

- Each block requires individual calibration
- Calibration changes with time
- Life of device limited
- Provides inaccurate measurements

3. Neutron scattering method

Fast neutrons are emitted by neutron emitters; viz. radium-beryllium or americium-beryllium. The fast-moving neutrons interact with the hydrogen atoms and get slowed down. The number of slow moving neutrons returned back after colliding with the hydrogen is proportional to the quantity of water present in the soil as water is considered to be the sole source of hydrogen atoms. The slow moving neutrons are detected by proportional or scintillation counters and interpreted in terms of moisture percentage at different depths.

Advantages

- Nondestructive
- Possible to obtain profile of water content in soil

Soil and Plant Analysis

- Water can be measured in any phase
- Can be automated for one site to monitor spatial and temporal soil water
- Measurement directly related to soil water content

Disadvantages

- Costly
- Dependent on dry bulk density and salinity
- Radiation hazard
- Must be calibrated for different types of soils
- Access tubes must be installed and removed
- Depth resolution questionable
- Measurement partially dependent on physical and chemical soil properties
- Depth probe cannot measure soil water near soil surface
- Subject to electrical drift and failure

4. Measuring soil moisture potential in-situ (field)-Suction method or equilibrium tension method

Field tensiometers measure the tension with which water is held in the soils. They are used in determining the need for irrigation. The tensiometer is a porous cup attached to a glass tube, which is connected to a mercury monometer. The tube and cup are filled with water and cup inserted in the soil. The water flows through the porous cup into the soil until equilibrium is established. These tension readings in monometer, expressed in terms of cm or atmosphere, measures the tension or suction of the soil. If the soil is dry, water moves through the porous cup, setting up a negative tension (or greater is the suction). The tensiometers are more useful in sandy soils than in fine textured soils and

can be used only up to a tension of 1 bar. At tensions above one bar the water column is broken and air enters the ceramic cup. Once the air gets entrapped in the tensiometer, the reliability of readings is questionable.

Advantages

- Recommendation for irrigation policy developed with the aid of tensiometers
- Inexpensive and easily constructed
- Works well in the saturated range
- Easy to install and maintain
- Operates for long periods if properly maintained
- Can be adapted to automatic measurement with pressure transducers
- Can be operated in frozen soil with ethylene glycol
- Can be used with positive or negative gauge to read water table elevation and/or soil water tension

Disadvantages

- Limit range of 0 to 0.8 bar not adequate for sandy soil
- Difficult to translate data to volume water content
- Hysteresis
- Requires regular (weekly or daily) maintenance, depending on range of measurements
- Subject to breakage during installation and cultural practices
- Automated systems costly and not electronically stable
- Disturbs soil above measurement point and can allow infiltration of irrigation water or rainfall along its stem.

5. Profile probe and theta probe

- This new technology uses electro-magnetic radiation.
- The emitted radiation is intercepted by soil water and the radiation reflected is detected and interpreted in terms of percent moisture content in different layers.

6. Pressure plate and pressure membrane apparatus

A pressure membrane apparatus is used to subject soils to matric potentials as low as 10,000 kPa. After application of specific potential to a set of samples, their soil water contents are determined gravimetrically. This important tool makes possible accurate measurement of water content over a wide range of matric potentials in a relatively shorter time. It is used, along with the tension plate, to obtain data to construct soil water characteristic curves.



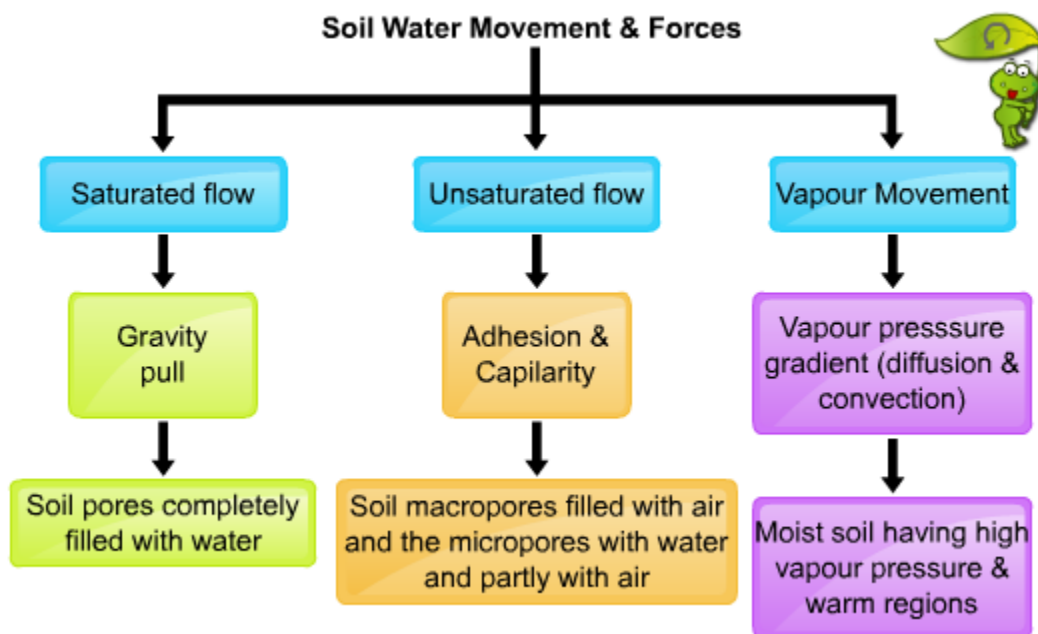
Lesson- 4

Hydraulic conductivity, Darcy’s Law and Determination of Hydraulic conductivity

Soil Water Movement

Three types of water movement within the soil are recognized. They are

- i) Saturated flow
- ii) Unsaturated flow
- iii) Water vapour movement



Saturated flow

This occurs when the soil pores are completely filled with water. This water moves at water potentials larger than 33 kPa. Saturated flow is water flow caused by gravity’s pull. It begins with infiltration, which is water movement into soil when rain or irrigation water is on the soil surface. When the soil profile is wetted, the movement of more water flowing through the wetted soil is termed percolation.

Hydraulic conductivity can be expressed mathematically as

$$V = kf$$

Where,

V = Total volume of water moved per unit time

f = Water moving force

k = Hydraulic conductivity of soil

Vertical water flow

Darcy’s law gives the vertical water flow rate through soil. The law states that the rate of flow of liquid or flux through a porous medium is proportional to the hydraulic gradient in the direction of flow of the liquid.

The quantity of water per unit time Q/t that flows through a column of saturated soil can be expressed by Darcy’s law as follows

$$Q/t = AK_{sat} \cdot \Delta\psi/L$$

Where A is the cross sectional area of the column through which the water flows, Ksat is the saturated hydraulic conductivity, $\Delta\psi$ is the change in water potential between the ends of the column (for example $\psi_1 - \psi_2$) and L is the length of the column. For a given column, the rate of flow is determined by the ease with which the soil transmits water (Ksat) and the amount of force driving the water, namely the water potential gradient $\Delta\psi / L$. For saturated flow this force may also be called as hydraulic gradient.

The units in which Ksat is measured are length / time, typically cm/s or cm/h. The Ksat is an important property that helps determine how well soil or soil material will perform in such uses as irrigated cropland, sanitary landfill cover material, waste water storage lagoon lining and septic tank drain field.

Values of saturated hydraulic conductivity and interpretation for soil uses

Ksat cm/h	Comments
36	Typically a beach sand
18	Typically a very sandy soil, too rapid to effectively filter pollutants in waste water
1.8	Typically a moderately permeable soil, Ksat between 1.0 and 15 cm/h considered suitable for most agricultural, recreational and urban uses calling for good drainage.

0.18	Typically a fine textured, compacted or poorly structured soils. Too slow for proper operation of septic tank drain fields, most types of irrigation and many recreational uses such as playgrounds.
$< 3.6 \times 10^{-5}$	Extremely slow, typical of compacted clay. Ksat of 10^{-5} to 10^{-8} cm/h may be required where nearly impermeable material is needed, as for wastewater lagoon lining or landfill cover material.

Factors influencing the hydraulic conductivity of saturated soils

Any factor affecting the size and configuration of soil pores will influence hydraulic conductivity. The total flow rate in soil pores is proportional to the fourth power of the radius. Thus, flow through a pore 1 mm in radius is equivalent to that in 10,000 pores with a radius of 0.1 mm even though it takes only 100 pores of radius 0.1mm to give the same cross-sectional area as a 1 mm pore. As a result, macropores (radius >0.05 mm) account for most water movement in saturated soils. The presence of bio-pores, such as root channels and earthworm burrows (typically >1 mm in radius) may have a marked influence on the saturated hydraulic conductivity of different soil horizons.

Because they usually have more macropore space, sandy soils generally have higher saturated hydraulic conductivities than fine-textured soils. Likewise, soils with stable granular structure conduct water much more rapidly than do those with unstable structural units, which break down upon being wetted. Saturated hydraulic conductivity of soils under natural vegetation is commonly much higher than in soils where cultivated crops have been grown. Entrapped air, which is common in recently wetted soils, can slow down the movement of water and thereby reduce the hydraulic conductivity.

Determination of saturated hydraulic conductivity

Saturated hydraulic conductivity (Ksat) of soil is generally determined in the laboratory

on undisturbed soil core with the help of either constant head permeameter or falling head permeameter. In the first method, undisturbed soil core is collected by depth core sampler. After covering the bottom end with a muslin cloth, the soil core is saturated by placing it in a trough of water. The saturated soil core is then placed in the constant head permeameter where water is allowed to flow through it under a constant head maintained by a constant head reservoir. The steady state outflow through soil core is measured and used for calculating K_{sat} by Darcy's law:

$$K_{sat} = -VL / At \Delta H$$

Where, V is the outflow volume of water, L is the length of soil, A is the cross-sectional area of the soil, t is the time and ΔH is the pressure head difference inflow and outflow ends.

(ii) Unsaturated flow

It is flow of water held with water potentials lower than 1/3 bar. Water will move toward the region of lower potential (towards the greater "pulling" force). In a uniform soil this means that water moves from wetter to drier areas. The water movement may be in any direction. The rate of flow is greater as the water potential gradient (the difference in potential between wet and dry) increases and as the size of water filled pores also increases. The two forces responsible for this movement are the attraction of soil solids for water (adhesion) and capillarity. Under field conditions this movement occurs when the soil macropores (non-capillary pores) with filled with air and the micropores (capillary pores) with water and partly with air.

Factors affecting the unsaturated flow

Unsaturated flow is also affected in a similar way to that of saturated flow. Amount of

moisture in the soil affects the unsaturated flow. The higher the percentage of water in the moist soil, the greater is the suction gradient and the more rapid is the delivery.

(iii) Water vapour movement

The movement of water vapour from soils takes place in two ways

(a) Internal movement – the change from the liquid to the vapour state takes place within the soil, that is, in the soil pores and

(b) External movement – the phenomenon occurs at the land surface and the resulting vapour is lost to the atmosphere by diffusion and convection.

The movement of water vapour through the diffusion mechanism takes place from one area to the other soil area depending on the vapour pressure gradient (moving force), this gradient being simply the difference in vapour pressure of two points a unit distance apart. The greater this difference, the more rapid the diffusion and the greater is the transfer of water vapour during a unit period.

Soil conditions affecting water vapour movement. There are mainly two soil conditions that affect the water vapour movement namely moisture regimes and thermal regimes. In addition to these, the various other factors which influence the moisture and thermal regimes of the soil are like organic matter, vegetative cover, soil colour etc. The movement takes place from moist soil having high vapour pressure to a dry soil (low vapour pressure). Similarly the movement takes place from warmer soil regions to cooler soil region. In dry soils some water movement takes place in the vapour form and such vapour movement has some practical implications in supplying water to drought resistant plants.

Entry of water into Soil

Infiltration

- Infiltration refers to the downward entry or movement of water into the soil surface
- It is a surface characteristic and hence primarily influenced by the condition of the surface soil.
- Soil surface with vegetative cover has more infiltration rate than bare soil
- Warm soils absorb more water than colder ones
- Coarse surface texture, granular structure and high organic matter content in surface soil, all help to increase the infiltration
- Infiltration rate is comparatively lower in wet soils than in dry soils

Factors affecting infiltration

- Clay minerals
- Soil texture
- Soil structure
- Moisture content
- Vegetative cover
- Topography

Percolation

- The movement of water through a column of soil is called percolation. It is important for two reasons. This is the only source of recharge of ground water which can be used through wells for irrigation. Percolating waters carry plant nutrients down and often out of reach of the plant roots (leaching)
- In dry region it is negligible and under high rainfall it is high
- Sandy soils have greater percolation than clayey soil
- Vegetation and high water-table reduce the percolation loss

Permeability

- It indicates the relative ease of movement of water within the soil. The characteristics that determine how fast air and water move through the soil is known as permeability.
- The term hydraulic conductivity is also used which refers to the readiness with which a soil transmits fluids through it.

Lesson- 5

Soil Air, Its Composition, Gaseous Exchange and Measurement of ODR

Introduction

Soil air is a continuation of the atmospheric air. It is in constant motion from the soil pores into the atmosphere and from the atmosphere into the pore space. The circulation of air in the soil and renewal of component gases like oxygen and carbon dioxide is known as soil aeration. Soil aeration is essential for the respiration and survival of soil organisms and plant roots.

Composition of soil air

Soil air contains gases like nitrogen, oxygen, carbon dioxide, water vapour and others. The composition of soil air is different from atmospheric air. Soil air contains more carbon dioxide and less oxygen than atmospheric air. It also contains more water vapour than atmospheric air. The nitrogen content of soil air is almost equal to atmospheric air.

Composition of soil and atmospheric air

Source	Per cent by volume		
	Nitrogen	Oxygen	Carbon dioxide
Soil air	79.2	20.0	0.35
Atmospheric air	79.0	21.0	0.03

Soil aeration problems in the field**Factors affecting the composition of soil air****Nature of soil**

- Soil with more pore space volume will have more air.
- The drainage of excess water from soil macropores improves soil aeration.
- If the volumes of soil macropores are high, soil aeration will be good.
- Soil texture, bulk density, aggregate stability and organic matter contents influence the soil macropores.
- The quantity of oxygen in soil air is less than that in atmospheric air.
- The oxygen content of the air reduces with increasing depth of soil.
- Surface soil will have more oxygen than sub soil because of quick replenishment from the atmospheric air through diffusion.

Soil and Plant Analysis

- Light textured soil or sandy soil contains more air than the heavy soil.
- The concentration of CO₂ is more in subsoil due to slow rate of replenishment and low aeration in lower layer than in the surface soil.
- High clay containing soils will have high soil moisture potential - which reduces the oxygen diffusion rate and increases the CO₂ accumulation.

Type of crop

- Plant roots require oxygen, which they take from the soil air and deplete the concentration of oxygen in the soil air and release CO₂.
- Soils on which crops are grown contain more CO₂ than fallow lands.
- The amount of CO₂ is more near the plant than farther away due to respiration by roots.

Microbial activity

- The microorganisms in soil require oxygen for respiration and they take it from the soil air depleting its concentration.
- Decomposition of organic matter produces CO₂, because of increased microbial activity.
- Hence, soils rich in organic matter contain higher CO₂.

Seasonal variations

- The oxygen content of soil air is higher in dry season than during the monsoon.
- During the dry season, most of the soil pores are filled with air and the exchange of gases between the soil air and the atmosphere is more.
- During monsoon seasons, most of the soil pores are filled with water.
- Temperature also influences the gaseous composition of the soil air.

Soil and Plant Analysis

- High temperature enhances the gaseous exchange between the soil air and the atmosphere.
- High temperature also increases the microbial respiration and releases more CO₂ in the soil air.
- Under field conditions, poor soil aeration occurs due to two conditions: a) when the moisture content is too high occupying most of the pore space and b) when the exchange of gases with the atmosphere is slow.
- When the field is completely submerged with water, all the plants except some plants like rice, die for want of oxygen.

Exchange of gases between soil and atmosphere

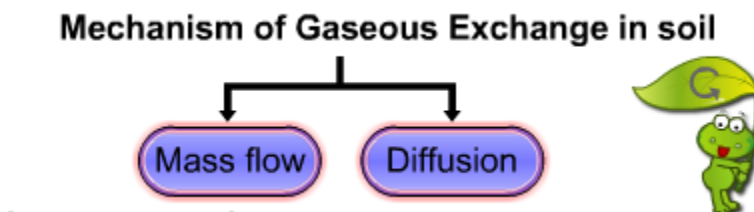
- The exchange of gases between the soil air and the atmosphere is facilitated by two mechanisms.

Mass flow

- During the rain fall or during irrigation, a part of the soil air is replaced by water and the replaced air moves out into the atmosphere.
- When the soil moisture is lost due to evaporation, plant absorption, internal drainage etc., atmospheric air reenters into the soil pore space.
- The variations in soil temperature cause changes in the temperature of the soil air.
- Also, when the soil air gets heated during the day, it expands and the expanded air moves out into the atmosphere.
- When the soil cools during the night, the soil air contracts and the atmospheric air is drawn in.

Diffusion

- Most of the gaseous interchange in soils occurs by diffusion.
- Atmosphere and soil air contains gases such as nitrogen, oxygen, carbon dioxide etc., each of which exerts its own partial pressure in proportion to its concentration.
- These gases move from higher concentration (higher partial pressure) to lower concentration (lower partial pressure).
- Oxygen moves from the atmosphere into soil (air) and CO₂ moves out of the soil air into the atmosphere through diffusion without the movement of entire air mass because of the difference in their concentration or partial pressure.
- This movement is called diffusion and this will continue till equilibrium is established.



Importance of soil aeration

Soil reactions and properties

Microbial breakdown of soil organic residues is reduced under poor aeration and hence organic matter is accumulated. In well-aerated soil, aerobic microorganisms are active and they convert simple sugars to CO₂ and water using oxygen. In submerged or reduced soil, anaerobic microorganisms are active and they convert sugars to less CO₂ and more CH₄ (methane) which is an atmospheric pollutant. This process also gives out some organic acid, ethylene gas etc., which are toxic to plant roots and some microbes. The aerobic decomposition will be faster than anaerobic decomposition.

Oxidation and reduction of inorganic elements

The oxidized state of nitrogen and sulphur are easily utilized by the plants. Reduced forms of some of the elements are toxic. Though solubility of iron and manganese increases, they become toxic to the plants.

Soil colour is also altered by aeration. Well-aerated soils have red, yellow and reddish brown colours. Reduced soils have grey and blue colours. The discolouration of soil in patches is called mottling.

Plant and root growth

Soil aeration is important factor for the normal growth of plants. Roots absorb oxygen for their respiration and release CO₂. The supply of oxygen to roots in adequate quantities and the removal of CO₂ from the soil air are very essential for healthy plant growth.

When the supply of oxygen is inadequate, the plant growth either slows or ceases completely as the accumulated CO₂ hampers the growth of plant roots. The abnormal effect of insufficient aeration on root development is most noticeable on the root crops.

Abnormally shaped roots of these plants are common on the compact and poorly aerated soils. The penetration and development of root are poor. Such undeveloped root system cannot absorb sufficient moisture and nutrients from the soil.

Microorganism population and activity

The microorganisms living in the soil also require oxygen for respiration and metabolism. Some of the important microbial activities such as the decomposition of organic matter, nitrification, sulphur oxidation etc., depend upon the amount of oxygen present in the soil air. The deficiency of oxygen in soil air slows down the rate of microbial activity. The decomposition of organic matter is retarded and nitrification arrested. The microorganism population is also drastically affected by poor aeration.

Formation of toxic material

Poor aeration results in the development of toxins and other injurious substances such as ferrous oxide, H₂S gas, CO₂ gas, ethylene, organic acids, etc., in the soil.

Water and nutrient absorption

A deficiency of oxygen has been found to check the nutrient and water absorption by the plants. The energy of respiration is utilized in absorption of water and nutrients. Under poor aeration in water-logged soils, plants exhibit water and nutrient deficiency.

Development of plant diseases

Insufficient aeration of soil leads to the development of some diseases like, wilt of gram and dieback of citrus and peach.

Measurement of soil aeration

Oxygen Diffusion Rate (ODR) - the rate at which O₂ in soil air is replenished. ODR decreases with soil depth.

Measurement of ODR in soil

Lemon and Erickson (1952) devised a method for measuring oxygen diffusion in the soil system with the help of platinum micro electrode

Principle

When a certain potential is applied across the platinum electrode and a reference electrode inserted in the soil, oxygen is reduced at the platinum surface. The electric current flowing between two electrodes is proportional to the rate of oxygen reduction. The later, in turn, is related to the rate of oxygen diffusion to the electrode. The oxygen diffusion rate is calculated from the measured electric current with the following equation

$$\text{ODR} = \frac{Mi}{nFA}$$

Where M is molecular wt of O₂, n is the number of electrons involved in the reduction of one molecule of oxygen, F is Faraday constant, i is current in amperes and A is the exposed surface (m²) of the electrode.



Oxygen diffusion probe

Oxygen diffusion meter

Oxygen diffusion meter

The oxygen diffusion meter(i,ii,iii) measures the mobility of oxygen in the soil that is important for the availability of oxygen for plants.

The method: measuring the electric current required for the reduction of all oxygen present at the surface of a cylindrical Pt-electrode in the soil. The flow of oxygen through the air-filled pores and the water film on the electrode is measured until the steady state is reached.

The Oxygen Diffusion Rate (ODR) probe (Pt-electrode) should be placed in undisturbed soil. To this purpose a hole is predrilled to a depth of approximately 10 mm above the measuring point, after which the probe is lowered and carefully pushed into the bottom of the auger-hole. It is advised to remove the electrode from the soil after a series of measurements in order to clean it. The meter provides a stabilized voltage between the ODR-probe and the Ag-AgCl-reference electrode.

In very dry soils only part of the electrode will be covered in water. This results in rising impedance between soil and electrode. In such a situation the meter can also be used to perform a redox-potential measurement.

The measuring system consists of a read-out unit with connecting facilities for three ODR-probes, one ODR-probe, one Ag-AgCl reference electrode, KCl-solution and a brass electrode. The reference electrode is used for measuring and checking the potential between the Pt-electrode and the soil. The brass electrode is used to close the electrical circuit. The measuring range for oxygen diffusion is 0 - 999 μ A and for Redox 0 - 999 mV

Soil and Plant Analysis

(resolution resp. 1 μA and 1 mV). Accuracy $\pm 3 \mu\text{A}$ and $\pm 3 \text{mV}$. Operating temperature between 0 and 50°C and an air humidity between 30 - 80%.



Lesson- 6

Plant sampling, importance, methods of sampling and processing of plant samples

Introduction

Plant analysis is based on the principle that the concentration of a nutrient within the plant is an integral value of all the factors that have interacted to influence it. Plant analysis involves the determination of nutrient concentration in diagnostic plant part(s) sampled at the recommended growth stage(s) of the crop.

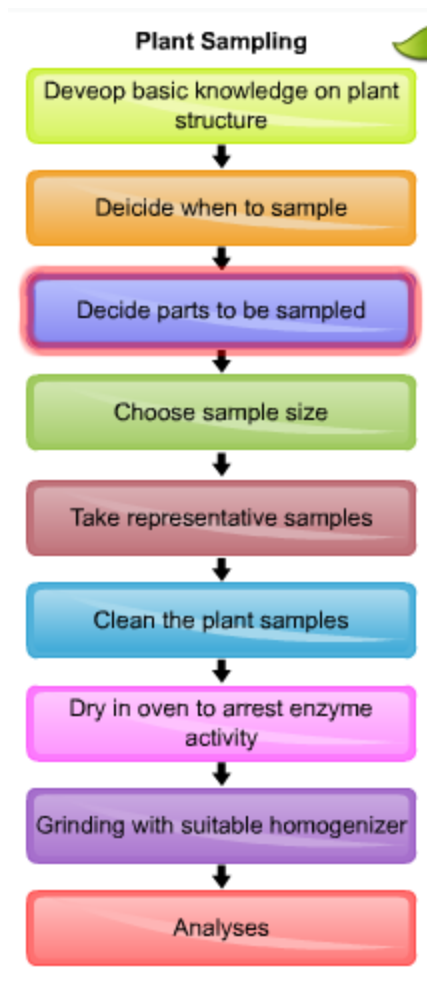
Importance

- Plant analysis assesses nutrient uptake while soil testing predicts nutrient availability.
- The two tests are complementary to each other as crop management tools.
- Plant analysis will detect unseen hidden hunger and confirm visual deficiency symptoms.
- Toxic levels may also be detected.
- If it is done early, plant analysis will allow a corrective fertilizer application in the same season.

Methods of plant sampling

- A basic knowledge of plant structure is necessary before collecting samples.
- A leaf is made up of a 'leaf blade' and a 'petiole'. The petiole is the stalk attached to the blade.
- A compound leaf may have several 'leaflets' attached to it.
- In some cases, only terminal 'leaflets' may be sampled, as in the case of walnuts and pistachios.
- A common error in tomatoes is when only leaflets are sampled instead of the whole compound leaf.

- This shows the importance of understanding proper sampling technique.
 - The most recent mature leaf (MRML) is the first fully expanded leaf below the growing point.
 - It is neither dull from age nor shiny green from immaturity.
 - For some crops, the most recent mature leaf is a compound leaf.
 - The most recent mature leaf on soybean and strawberry, for example, is a trifoliolate compound leaf: three leaflets comprising one leaf.
 - For cotton, grape, potato and strawberry, petioles provide an additional indication of nitrogen status.
 - When sampling these crops, collect most recent mature leaves and their petioles. Detach leaves from petioles in the field to stop the translocation of nutrients.
 - Put petioles in a separate bag. "Midribs" are the middle ribs to large leaves such as corn, lettuce, and cabbage, and would equate to a petiole sampling.



Deciding when to sample

- To monitor plant nutrient status most effectively, sample during the recommended growth stages of the specific crop.
- Take samples weekly or biweekly during critical periods, depending on management intensity and crop value.
- However, to identify a specific plant growth problem, take samples whenever you suspect the problem.
- The best time to collect samples is between mid-morning and mid-afternoon.
- Nitrate nitrogen varies with time of day and prevailing conditions but generally not enough to alter interpretation.

Soil and Plant Analysis

- Sampling during damp conditions is okay but requires extra care to prevent tissue from decomposing during shipping.
- Keep samples free of soil and other contaminants that can alter results.
- The appropriate part of the plant to sample varies with the crop, stage of growth, and purpose of sampling.
- When sampling seedlings less than 4 inches tall, take whole plants from 1 inch above the soil line.
- For larger plants, the most recent mature leaf is the best indicator sample.
- Taking a representative sample
- Proper sampling is the key to reliable plant analysis results. A sample can represent the status of one plant or 20 acres of plants. In general, a common-sense approach works well.
- In problem solving, take samples from both 'good' and 'bad' areas. Comparison between the two groups of samples helps to pinpoint the limiting element.
- Comparative sampling also helps factor to out the influence of drought stress, disease, or injury.
- Take matching soil samples from the root zones of both 'good' and 'bad' plants for the most complete evaluation.
- When monitoring the status of healthy plants, take samples from a uniform area.
- If the entire field is uniform, one sample can represent a number of acres.
- If there are variations in soil type, topography, or crop history, take multiple samples so that each unique area is represented by its own sample.

Choosing sample size

- The actual laboratory analysis requires less than one gram of tissue. However, a good sample contains enough leaves to represent the area sampled. Therefore, the larger the area is, the larger the sample size needs to be.
- Sample size also varies with the crop.
- For crops with large leaves like tobacco, a sample of three or four leaves is adequate. For crops with small leaves, like azalea, a sample of 25 to 30 leaves is more appropriate.
- For most crops, 8 to 15 leaves are adequate. For crops requiring petiole analysis, collect at least 15 to 20 leaves.

The table below shows the sampling guide for various crops

Crop	When to Sample	Where to Sample	Quantity
Field Crops			
Alfalfa	Early bloom stage	Upper 1/3 of plant	12 - 30
Canola	Before seed set	Recently mature leaf	60 - 70
Clover	Before bloom	Upper 1/3 of plant	30 - 40
Corn / Sweet Corn	Seedling stage Before heading Tasseling to silking	All above ground portion Upper 4 leaves Opposite or below ear leaf	15 - 20 12 - 20 12 - 20
Grasses/forage mixes	Stage of best quality	Upper 4 leaves	30 - 40
Peanuts	Before / at bloom	Recently mature leaf	40 - 50
Small grains (barley, wheat, oat, rye, rice)	Seedling stage Before heading	All above ground portion Upper 4 leaves	25 - 40 25 - 40
Sorghum	Before / at heading	2nd leaf from top	23 - 30
Soybeans	Before / at bloom	recently mature leaf	20 - 30
Sugarbeets	Midseason	recently mature leaf at center of whorl	15 - 20
Sunflower	Before heading	Recently mature leaf	20 - 30
Tobacco	Before bloom	Recently mature leaf	10 - 15
Vegetable crops			
Asparagus	Maturity	Fern from 18 - 30 inches up	10 - 30
Beans	Seedling stage Before / at bloom	All above ground portion Recently mature leaf	20 - 30 20 - 30




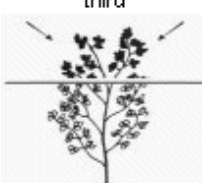

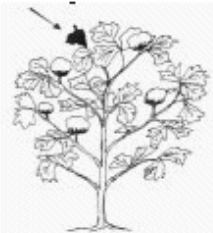



Broccoli	Before heading	Recently mature leaf	12 - 20
Brussel sprouts	Midseason	Recently mature leaf	12 - 20
Celery	Midseason	Outer petiole	12 - 20
Cucumbers	Before fruit set	Recently mature leaf	12 - 20
Head crops (Cabbage / cauliflower)	Before heading	Recently mature leaf at center of whorl	12 - 20
Leaf crops (lettuce, spinach etc)	Midseason	Recently mature leaf	12 - 20
Melons	Before fruit set	Recently mature leaf	12 - 20
Peas	Before / at bloom	Leaves from 3rd node from top	40 - 60
Peppers	Midseason	Recently mature leaf	25 - 50
Potatoes	Before / at bloom	3rd - 6th leaf from growing tip	40 - 60
Root / bulb crops (carrots, beets, onions etc)	Midseason before root or bulb enlargement	Recently mature leaf	20 - 30
Tomatoes	Mid - bloom	3rd - 4th leaf from growing tip	15 - 20
Tomatoes (indeterminate)	Mid-bloom from 1st to 6th cluster stage	Leaf below or opposite top cluster	12 - 20
Fruits and Nut crops			
Apple, pears, almonds, apricots, cherries, prunes, plums	Midseason (June - July)	Leaves from current season's non-fruiting non-expanding spurs	50 - 100
Olives, peaches, Figs	Midseason (June - July)	Basal to mid- shoots leaves from current season's non fruiting shoots	25 - 100
Blueberries	2 - 4 weeks before harvest	Mid-shoot leaves from current season's shoots	50 - 100
Citrus	Late season (Aug.)	Terminal leaves from current season's non-fruiting shoots	25 - 40
Grapes	Mid-bloom	Recently mature petioles or leaves adjacent to basal clusters	50 - 100
Kiwi fruit	Mid season	1st - 3rd leaf beyond fruit or mid-cane leaves if non- bearing	50 - 60
Pecans	Midseason	Paired mid-shoot leaflets from non-fruiting shoots	25 - 60
Raspberries	Midseason	Recently mature leaves from laterals of primo canes	25 - 60










Soil and Plant Analysis

Strawberries	Midseason	Recently mature leaves	25 - 40
Walnuts	Midseason (June - July)	Terminal leaflets from non-fruited shoots	25 - 40
Ornamentals and flowers			
Carnations	Newly planted	4th - 5th pair from base	20 - 30
	Established		20 - 30
Chrysanthemums	Before / at bloom	Top leaves on flowering stem	20 - 30
Ornamental trees and shrubs	Current years growth	Recently mature leaf	30 - 70
Roses	At bloom	Recently mature compound	15 - 20
Turf	Active growth	Leaf blades. Avoid soil contamination	2 cups

- In some specific cases, based on the nutrient to be analyzed, the sampling parts of the plant may vary.
- When leaves are sampled, recently matured ones are taken; both new and old growth is generally avoided.
- However, young emerging leaves are sampled for diagnosing iron chlorosis by determining ferrous (Fe^{++}) content of fresh leaves and B content in certain crops.
- Plant samples should be transported to the laboratory immediately in properly labeled paper.
- If samples are very wet, air-dry to a workable condition before packaging. Otherwise, decomposition or molding will occur.
- Include a completed plant analysis information sheet or cover letter with instructions within the same package.

Graphic Sampling Guides for some Common Crops

<p>Corn...before tasseling 1st fully developed leaf</p> 	<p>Small grains 4 uppermost leaves</p> 	<p>Rice Flag or Y leaf</p> 	<p>Alfalfa, Clover Top 6 inches or upper third</p> 	<p>Beans, Peas Recently mature trifoliolate</p> 
<p>Cotton Leaves/petioles from 4th - 5th node</p> 	<p>Tomatoes, Peppers 4th - 5th leaf from tip</p> 	<p>Potatoes 4th - 5th leaf from tip</p> 	<p>Melons, Squash, Pumpkins 5th - 6th leaf from tip</p> 	

<p>Lettuce, Cabbage Wrapper leaf, heading</p> 	<p>Broccoli, Cauliflower Recently mature leaf, buttoning</p> 	<p>Carrots Tallest leaf</p> 	<p>Onions, Garlic Tallest leaf, before bulbing</p> 	<p>Beet Tallest leaf</p> 
<p>Pecans, Figs, Olives, Peaches, Nectarines Midshoot leaflets/leaves</p> 	<p>Pistachios, Walnuts, Citrus Terminal leaflets/leaves</p>  <p>Apples, Pears, Almonds, Apricots, Cherries, Prunes, Plums Leaves from non-fruiting non-expanding spurs</p>	<p>Grapes Leaves/petioles opposite basal cluster or 6th - 7th leaf from tip at fruit ripening</p> 	<p>Strawberries Early fruiting Recently mature leaf</p> 	

Laboratory processing

Five steps are followed for processing the sampled plant tissues:

1. Cleaning plant tissue to remove dust, pesticide and fertilizer residue normally by washing the plants with de-ionized water or with 0.1 to 0.3 % P-free detergents,

Soil and Plant Analysis

followed by deionized (DI) water. If not essentially required, samples for soluble element determination may not be washed, particularly for long periods. However, samples for total iron analysis must be washed. Immediate drying in an oven to stop enzymatic activity, usually at 65°C for 24 hours.

2. Mechanical grinding to produce a material suitable for analysis, usually to pass a 60-mesh sieve; stainless mills are preferable, particularly when micronutrients analysis is involved.
3. Since most analytical methods require grinding of a dry sample, careful attention must be given to avoid contamination with the element to be analyzed. Particular care is required for micronutrients (metal grinder should not be used for micronutrients analysis).
4. Final drying at 65°C of ground tissue to obtain a constant weight.

Moisture factor

Weighing of perfectly oven-dried samples is, however cumbersome (involves continuous oven-drying and use of desiccator, and is still prone to error) as plant material may absorb moisture during the weighing process, particularly if relative humidity is high in the laboratory.

To get over this difficulty, use of the moisture factor is suggested instead. The moisture factor for each batch of samples can be calculated, by oven-drying only a few subsamples from the lot (e.g. 5 from a batch of 100-200 samples).

Weight of air dry sample (g)

$$\text{Moisture factor} = \frac{\text{Weight of air dry sample (g)}}{\text{Weight of oven dry sample (g)}} \text{----- (1)}$$

Weight of oven dry sample (g)

Thereafter, air dry samples are weighed, considering the moisture factor. For example, if moisture factor = 1.09, then weight of oven dry and air dry samples will be as follows.

Oven dry weight	Air dry weight
0.25	0.27
0.50	0.55
1.00	1.09
2.00	2.18

The moisture factor approach is also used for weighing soil samples, and expressing the analytical results on oven dry soil weight basis.



Lesson- 7

Leaf analysis, standards and index tissues of different crops and interpretation of leaf analytical values

Leaf analysis

Leaf analysis (also called stem leaf analysis, tissue analysis or foliar analysis) is the most precise method of monitoring plant nutrient levels.

While soil analysis reveals the levels of essential soil nutrients, leaf analysis shows the grower exactly what the plant has successfully absorbed.

Leaf analysis is especially helpful in detecting nutrient deficiencies before they affect plant health and yield.

Importance

Chemical analysis of plant foliage is an important tool for establishing and maintaining a proper fertilizer programme in soil fertility management especially for fruit plantings.

Leaf analysis can be used to confirm or diagnose a problem associated with a nutrient shortage or excess, and more importantly to prevent the development of a nutrient disorder in crops.

It would also reveal that certain fertilizers being used are not necessary and results in the most economical fertilizer programme.

Analysis must be properly taken.

In other instances, a series of analyses may be necessary to arrive at a proper explanation.

Paired comparisons, one from normal and one from the abnormal condition, are frequently helpful.

Foliar analyses made over a period of years can indicate an approaching deficiency of a nutrient element before the plant shows any visible symptoms.

Soil and Plant Analysis

It is possible then, through proper corrective fertilizer applications, to prevent the deficiency from ever occurring in the crop. B

y the same token, it is possible to learn when an element may be increasing in a crop toward a level that will reduce crop quality or bring about some other undesirable effect.

When this condition is known, steps can be taken to alter the fertilizer programme and cultural practices that influence the uptake of the element from the soil.

What plant tissue analysis shows?

Plant tissue analysis shows the nutrient status of plants at the time of sampling.

- This, in turn, shows whether soil nutrient supplies are adequate. In addition, plant tissue analysis will detect unseen deficiencies and may confirm visual symptoms of the deficiencies. Toxic levels also may be detected. Though usually used as a diagnostic tool for future correction of nutrient problems, plant tissue analysis from young plants will allow a corrective fertilizer application during the same season. Not all abnormal appearances are due to a deficiency.
- Some may be due to too much of certain elements. Also, symptoms of one deficiency may look like those of another.
- A plant tissue analysis can pinpoint the cause, if it is nutritional.

A plant analysis is of little value

- if the plants come from fields that are infested with weeds, insects, and disease organisms;
- if the plants are stressed for moisture; or
- if the plants have some mechanical injury.

The most important use of plant analysis is as a monitoring tool for determining the adequacy of current fertilization practices. Sampling a crop periodically during the season or once each year provides a record of its nutrient content that can be used through the growing season or from year to year. With soil test information and a plant analysis report, a producer can closely tailor fertilization practices to specific soil-plant needs. It also may be possible to prevent nutrient stress in a crop if the plant analysis indicates a potential problem developing early in the season. Corrective measures can be applied during the season or, if the crop is perennial, during the next year. Combined with data from a soil analysis, a tissue analysis is an important tool in determining nutrient requirements of a crop.

Download Recommended plant tissue nutrient levels: sufficiency values and ranges

INTERPRETATION

- The sufficiency ranges are given for plant tissues of the crops at ages (or stages in the crop cycle) that research has found appropriate for sampling.
- The analysis data can be used as a guide for attaining improved crop quality and yield.
- For long-term orchard crops, plant tissue nutrient levels can be logged over time and used as a diagnostic tool to assist in developing a fertilizer programme.
- If a tissue level of a nutrient is below the lower end of the sufficiency range, the nutrient should be considered deficient, whereas if the level is above the upper end of the range, the nutrient can be considered as approaching a toxic level.
- The midpoint of the sufficiency range is the target to aim at.

Soil and Plant Analysis

- As the level approaches the lower limit, the nutrient should be added.
- As the level approaches the upper limit, additions of the nutrient should be withheld. It is important to be near the midpoint for most nutrients, because imbalances in the ratios of nutrients can affect crop growth.
- Because environment plays a major role in nutrient uptake and crop development, the sufficiency ranges given here should be considered as general guides.
- In addition to variation due to environment effects, different crop cultivars may have different critical levels.



Lesson- 8

Chemical and mineralogical composition of important horticultural crops

Introduction

The living plant is constituted of various organic compounds, which in turn are made up of several inorganic elements. The organic compounds to which the plant can be resolved at the first disintegration are called proximate constituents. The inorganic elements to which the plant can be finally decomposed are called ultimate components.

Proximate constituents are as follows:

1.	Water	:	80-95 %
2.	Carbohydrates:	:	1-5 %
	a. Sugars and starches		10-30 %
	b. Hemicelluloses		20-30%
	c. Celluloses		
3.	Proteins	:	1-15 %
4.	Lipids	:	1-8 %
5.	Plant pigments, alkaloids, tannins and essential oils	:	1-8 %
6.	Plant growth substances (enzymes, vitamins and hormones)	:	Small amounts
7.	Mineral elements	:	2 - 5 %

Ultimate components are: the inorganic elements which make up the plant body Viz. C, H, O, N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Mo and Cl.

CHEMISTRY OF VEGETABLE CROPS

- Vegetables play an important role in human nutrition supplying some of the materials, which other food materials are lacking.
- Vegetables are important in neutralizing the acidity formed during digestion.
- They also serve as roughages in human nutrition and thus helping digestion.
- They are the important sources of minerals like Ca, P and Fe.
- They also form an important source of vitamins, especially vitamin A.

Soil and Plant Analysis

- Green and yellow vegetables like carrot, turnip, spinach, beans, etc. contain appreciable amounts of vitamin A.
- Direct seed of beans, peas, and legumes contain appreciable amounts of proteins.
- Vegetables also contain sufficient amounts of vitamin C and also appreciable quantities of thiamine, niacin and folic acid.
- Tomatoes and potatoes contain fairly high amounts of vitamin C.

POTATO (*Solanum tuberosum*)

- Starch accounts for 65-80% of the dry weight of the tuber.
- The important sugars are glucose, fructose and sucrose.
- The N content varies from 1.2 to 2.0 per cent on dry weight basis.
- Of the total N, less than half is present as protein.
- 35-60% of N consists of free amino acids, oxides and nitrogenous bases.
- The principal protein of potato is a globulin fractionated into two fractions, tuberin and globulin II.
- The enzymes are phosphorylases, α and β amylases and phosphatases.
- Potatoes are good source for vitamin A and C. Riboflavin, thiamine and nicotinic acid are also present.
- The average fat content of the potato tuber is 0.1% in fresh weight basis.
- Citric and malic acids are the important organic acids present in potato.
- Solanine is the term applied to steroidal glycoalkaloid of potatoes.

TOMATO (*Solanum Lycopersicum*)

It is popularly praised vegetable commonly known as 'Love apple'. The nutrient content / 100 g of tomato are as follows:

Water	94.1%
Protein	1.0%
Fibre	0.6%
Fat	0.3%
Carbohydrate	4.0%

Minerals

Na	3 mg	Fe	0.6 mg
K	268 mg	Cu	0.1 mg
Ca	11 mg	Mn	0.19 mg
Mg	11 mg	P	27 mg
S	11 mg	Cl	51 mg

Vitamins

Vit. A	1100 IU
Vit. C	23 mg
Vit. E	0.27 mg
Vit. B	0.2 mg
Nicotinic acid	0.6 mg

Sugar content is 1.85 - 4.27%.

Acidity	4.2 - 10.2 mg of acid / 100 ml
Ascorbic acid	20.9 - 22.5 mg / 100 g

It is an excellent source of Vitamin C, so it is commonly known as poor man's orange. It is popular salad vegetable. It is used for the preparation of soups, pickles, ketchups etc.

Tomato juice is a popular appetizer and beverage.

CARROT (*Daucus carota*)

The nutrient content of the carrot per 100 g edible portion is as follows:

Water	82.2%
Energy	45 calories
Protein	1.2%
Vit. A	12,000 I.U
Thiamine	0.042 mg
Riboflavin	0.043 mg
Niacin	0.21 mg
Ca	42 mg
Vit. C	4 mg

BEETROOT (*Beta vulgaris*)

100 g of fresh Egyptian table beet root contains.

Protein	1.46 g	CHO	9.03 g
Fat	0.09 g	Ca	27 mg
Fibre	0.08 g	Cl	56 mg
Ash	0.89 g	Vit. A	19 I.U
Fe	0.8 mg	Vit. B	0.021 mg
Vit. B1	0.049 mg	Vit. C	5.5 mg

The tops are rich in vitamin and high in Ca and Fe. Small beets are excellent green leaf vegetable.

COWPEA (*Vigna sinensis* L.)

The nutrients contents of cowpea are given per 100 g edible portion.

Moisture	84.6%
Fat	0.2 g
Fibre	2.0 g
Calories	51
P	74 mg
Vit. A	941 IU
Riboflavin	0.09 mg
Vit. C	13 mg
Protein	4.3 g
Minerals	0.9 g
CHO	8.0 mg
Ca	80 mg
Fe	2.5 mg
Thiamine	0.07 mg
Nicotinic acid	0.9 mg

FIELD BEANS (*Dolichos lablab*)

Dolichos bean is rich in its nutritive value. The average chemical composition is as follows:

Moisture	86.1 g	Vit. A	312 I.U
Fat	0.7 g	Riboflavin	0.06mg
Calories	48	Ca	210 mg
Fibre	1.8 g	Oxalic acid	1 mg
Protein	3.8 g	Fe	1.7 mg
minerals	0.9 g	K	74 mg
CHO	6.7 g	S	40 mg
Mg	34 mg	Thiamine	0.1 mg
P	68 mg	Nicotinic acid	0.7 mg
Na	55.4 mg	Vit. C	9 mg
Cu	0.13 mg		

It is primarily grown for green pods, which are cooked as vegetables like other beans. The dry bean seeds also collected for various vegetable purposes.

ONION (*Allium cepa*)

The chemical composition per 100g of onion is as follows:

Moisture	86.8%
Protein	1.2%
Fat	0.1%
CHO	11.5%
Ca	0.18%
P	0.05%
Fe	0.7 mg
Vit. B	80 mg
Riboflavin	10 mg
Nicotinic acid	0.4 mg
Ascorbic acid	11.0 mg

Immature and mature bulbs are used as vegetable. The pungency, which is due to a volatile oil known as allylpropyl disulphide.

CABBAGE (*Brassica oleracea* var. *capitata*)

The chemical composition per 100 g of fresh cabbage is detailed below:

Water	92.1 g	Vit. B2	0.04 mg
Protein	1.4 g	Vit. B6	0.11 mg
Total fats	2 g	Vit. C	46 mg
Total CHO	5.7 g	P	28 mg
Fibre	1.5 g	Ca	46 mg
Vit. A	70 I. U	K	227 mg
Vit. B1	0.04 g	Na	13 mg

CAULIFLOWER (*Brassica oleracea* var. *botrytis*)

The composition per 100 g of cauliflower is as follows:

Water	91.7%	Vit. A	40 I. U
Energy	31 calories	Ascorbic acid	70 mg
Protein	2.4 g	Thiamine	0.2 mg
Ca	22 mg	Riboflavin	0.1 mg
Niacin	0.57 mg		

Cauliflower seedlings are used for salad and green. The curd is used in curries, soups and pickles. In abundant areas of production cauliflower curd is cut into pieces, dried and procured for off-season use.

RADISH (*Raphanus sativus*)

The nutritive value of radish roots per 100 g of edible portion is as follows:

Moisture	94.4 g	Ca	50 mg
Protein	0.7 g	Oxalic acid	9 mg
Fat	0.1 g	P	22 mg
Minerals	0.6 g	Fe	0.4 mg
Fibre	0.8 g	Na	33 mg
CHO	3.48 g	K	138 mg
Calories	17	Vit. A	5 I.U
Thiamine	0.06 g	Riboflavin	0.02 mg
Nicotinic acid	0.5 mg	Vit. C	15 mg

In leaves:

Water	89.1%	P	0.06%
protein	3.9%	Fe	0.8 mg
Fat	0.6%	Vit. A	81 I.U
Nicotinic acid	1.4 mg	Riboflavin	2.7 mg

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CHO	4.1%	Vit. B	21 mg
Ca	0.31%	Vit. C	21 mg

Fleshy roots are eaten raw or in salad or cooked. Fruits cooked and used as vegetables. It is very tasty when both roots and leaves are cooked together. Fleshy roots are eaten raw or in salad or cooked. Fruits cooked and used as vegetables. It is very tasty when both roots and leaves are cooked together.

MORINGA (*Moringa derifera*)

The composition of moringa is as follows:

Moisture	75.0%	Iodine	51 mg / kg
Protein	6.7%	Carotene	11.300 I.U
Fat	1.7%	Vitamin B1	210 mg / g
CHO	13.4%	Nicotinic acid	0.8 mg / 100 g
Fibre	0.9%	Ascorbic acid	220 mg / 100 g
Mineral matter	2.3%	Tocopherol	7.4 mg / 100 g
Ca	440 mg / 100 g	Fe	7.0 mg / 100 g
P	70 mg / 100 g		

Leaf protein contains the following amino acids: (mg / 100 g N)

Arginine	6.0	Methionine	2.0
Histine	2.1	Threonine	4.9
Lysine	4.3	Leucine	9.3
Tryptophan	1.9	Isoleucine	6.3
Phenylalanine	6.4	Valine	7.1

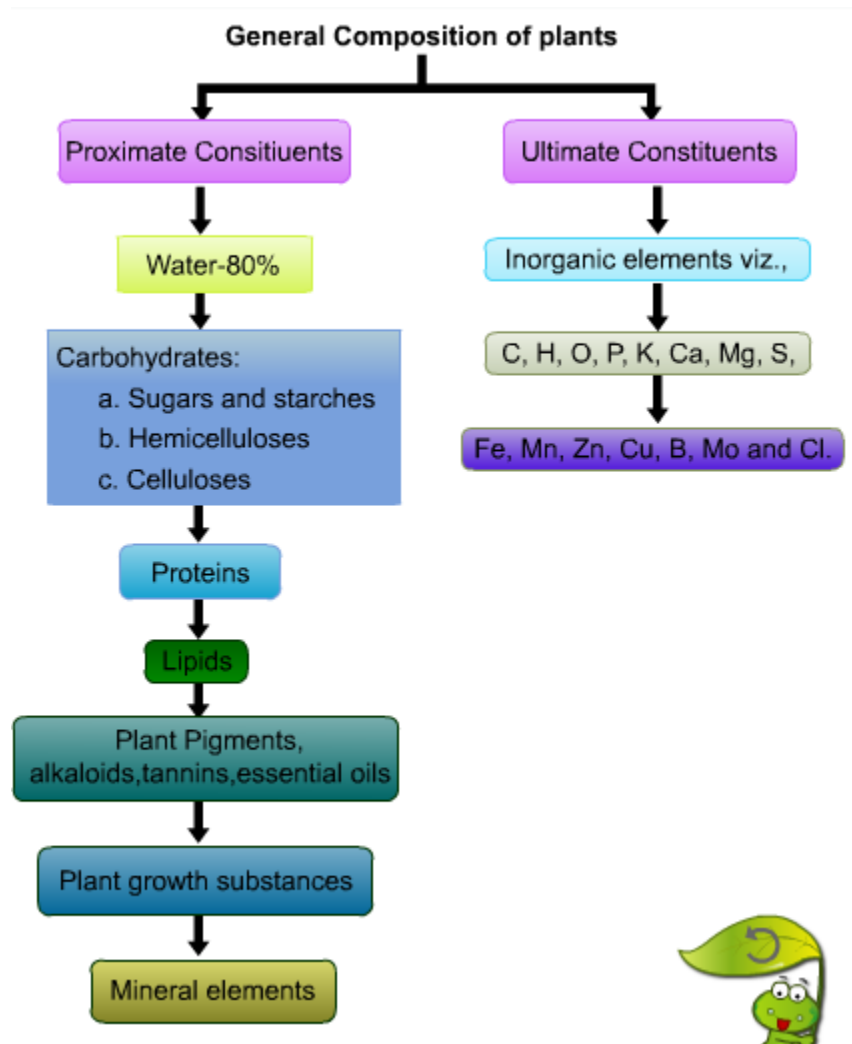
Kernel of seed contains

Moisture	4.0 %
Crude protein	38.4 %
Fatty oil	34.7 %
Nitrogen free extract	16.4 %
Fibre	3.5 %
Mineral matter	3.2 %

The fruits, leaves and flowers are used in culinary preparations. Immature fruits are cut into pieces and used in several culinary dishes after scraping of tough skin. The seed yields valuable oil known as 'oil of ben' valued by watchmakers for lubricating delicate machines.

Chemical composition of vegetables

S. No	Crop	Moisture (%)	Proteins (%)	CHO's	Fats (%)	Ca	P (mg/100g)	Fe
1.	Chillies	85.7	2.9	3.0	0.6	30	24	1.2
2.	Brinjal	92.7	1.1	5.5	0.2	0.15	0.48	0.01
3.	Bottle guard	96.4	0.2	2.5	0.1	20	5	0.7
4.	Pumpkin	92.6	1.4	4.6	0.1	10	14	0.7
5.	Bhendi	89.6	1.9	3.4	0.2	60	43	1.5
6.	Turnip	91.6	0.5	6.2	0.2	30	-	0.4
7.	Garlic	62.0	6.3	29.0	0.1	30	-	1.8
8.	Knoolkhol	92.7	1.1	3.8	0.2	20	18	0.4
9.	Bitter gourd	83.2	2.1	9.8	1.0	50	21	9.4
10.	Amaranthus	85.0	4.0	6.3	0.5	397	247	25.5



CHEMISTRY OF FRUITS

Fruits are valued for their attractive appearance, flavour and texture for a long time. In recent years their vitamin content has been recognized as an important feature. In all these characteristics, sugars either in the free stage or as derivatives play an important role. Flavour is fundamentally the result of the balance between sugars and acids. Certain flavouring constituents which are mostly glucosides also add to the flavour of the fruits.

I. Sugars

The sugar content varies from traces to 61% in fruits. Traces of sugars are present in lime and 61% in date. Sugars other than glucose, fructose and sucrose are rarely present. The average sugar content varies from 5-10%.

Apple	6-16%
Pineapple	8-18%
Grapes	10-19%
Mango	14%
Date	61%
Tomato	2-4%
Lemon	0.9-3.6

II. Proteins

The protein content of fruits is comparatively very low. The protein content varies with species, locality, season, cultural practices and other environmental factors.

Apple	0.2%	Grapes	1.3%
Banana	1.1%	Guava	0.8%
Avocado	2.1%	Lime, mango and pineapple	<1%
Tomato	1.2%	Dates	2.2%

III. Volatile compounds

The characteristic odour of many fruits is due to the presence of certain volatile compounds. These volatile compounds of the fruits are usually less than 100 ppm in concentration.

This group generally includes esters but compounds such as alcohols, aldehydes, ketons etc. are also found to possess pleasant aroma.

Apple	Ethyl 2 methyl butyrate
Grapes	Methyl anthranilate
Banana	Amyl acetate and isopentyl acetate
Grape fruit	Terpenes

Lemon: Hydrocarbon containing isoprene units and their oxygenated derivatives.

Orange: Limonene.

IV. Fruit phenolic compounds

Phenolic compounds are responsible for colour flavour and taste. These compounds give both desirable and undesirable qualities in fruits. The fruit phenolic compounds include both "Flavonoids" and "Cinnamic acid". The major flavonoids are anthocyanin, leucoanthocyanin, flavones and flavonols. Cinnamic acid and its derivatives are not flavonoids but related to them. The presence of these phenolic substances in fruits gives an astringent taste.



Lesson- 9

Principle and measurement of pH, EC and redox potential

pH

The most important characteristic of the soil solution is its reaction. The soil reaction describes the degree of acidity or alkalinity. The acidity or alkalinity is expressed in terms of concentration of H ions or OH ions. pH values are used to express the concentration of H or OH ion. Sorenson (1909) devised the present pH scale.

Water is a neutral substance with equal concentration of H and OH ions. The ionization constant of water is 10^{-14} . That is at neutral, the concentration of products of (H⁺) and (OH⁻) is 10^{-14} g/l. The pH scale ranges from 0-14.

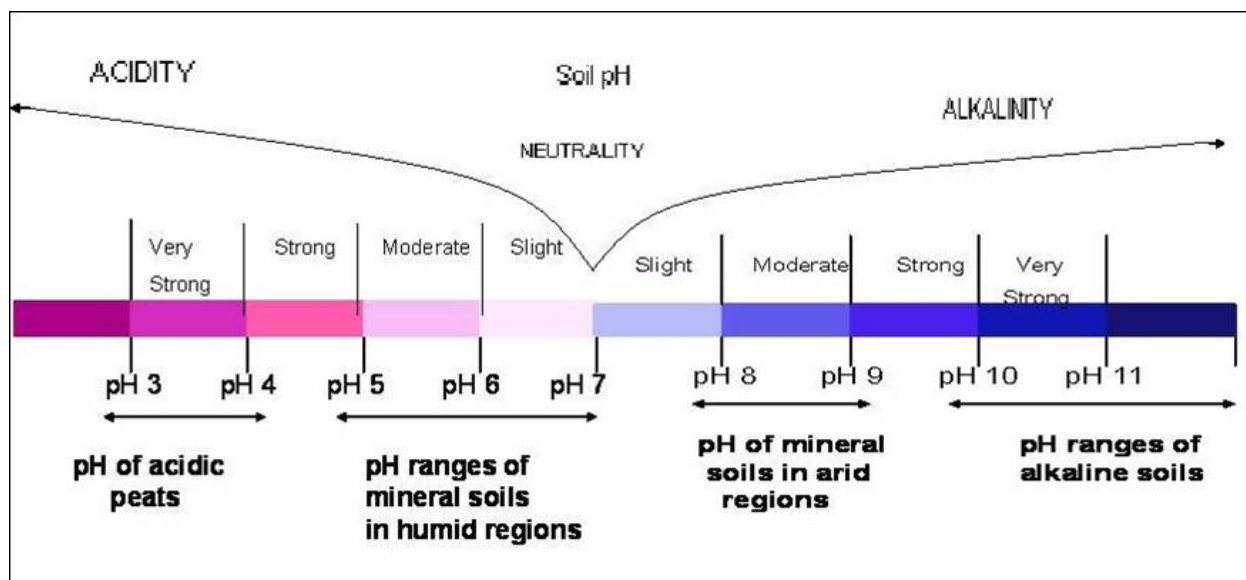
$$\text{Conc.H}^+ \times \text{Conc OH}^- = K_w = 10^{-14}$$

At neutral the concentration of H⁺ = 10^{-7} or = 0.0000001 g/l.

The reciprocal of this is $1/0.0000001 = \log 10 10000000$ the log of which is 7.

Thus the pH can be defined as the logarithm of reciprocal of H⁺ ion concentration or the negative logarithm of H ion concentration (hydrogen ion activity). It is also called as soil reaction.

If the concentration of H ion in a solution is 0.000001 g/l (10^{-6}) the pH is 6.0. Then at pH 6 the concentration of H ion is 10 times more as compared to that at pH 7. Since the product of concentration of H⁺ and OH⁻ ions is always equal to 10^{-14} we can know the concentration of OH⁻ ions if we know the pH value. A pH of 6.0 would indicate the concentration of OH⁻ ions as 10^{-8} . Since the soil acidity is mainly due to H⁺ ions a pH 7.0 indicates neutrality as the concentration of H⁺ and OH⁻ are equal. Above pH 7.0 the concentration of OH⁻ is more and it indicates alkalinity.



pH measurement

Principle:

A glass electrode in contact with H^+ ions of the solution acquires an electric potential which depends on the concentration of H^+ ions. This is measured potentiometrically against some reference electrode, which is usually a calomel electrode. The potential difference between glass electrode and calomel electrode is expressed in pH units.

Two electrodes are used in the determination of pH. One is reference electrode, which provides a standard voltage. The reference electrode is usually a saturated calomel electrode which has two layers

- (1) Saturated solution of KCl and
- (2) mixture of solid $HgCl_2$ and Hg.

The outer tube is usually 5-15 cm long, 0.5-1 cm in diameter. The mixture of solid $HgCl_2 + Hg$ paste is contained in an inner tube that is connected to the saturated KCl solution in the outer tube by means of small opening. The resistance of this type of electrode is 2000-3000 ohms.

The outer electrode is glass electrode that consists of a tube enclosing a lead wire made of Ag coated with $AgCl_2$. This wire is again enclosed in wax insulation. To the tube at the bottom is attached a glass bulb made of a special kind of glass which is sensitive to H^+ ions. The thickness of the glass membrane varies from 0.03 to 0.1 mm and has a resistance of 50 to 500 mega ohms.

When these two electrodes are dipped in solution, the saturated solution of KCl comes out of reference electrode through the small holes and forms an invisible ionic bridge between electrodes through which current passes. The H^+ ions are absorbed by glass electrode and

Soil and Plant Analysis

depending on the amount of H ions present in the solution, an electric potential develops between electrodes. This potential difference is measured in terms of pH by suitable galvanometer.

Materials required:

i) pH meter ii) 100 ml beakers iii) Glass rod iv) Buffer solutions (pH 4.0, 7.0 and 9.2)

Procedure:

- Standardization of pH meter
- Switch on the instrument and allow it to warm up for 10 minutes. Keep the pH selector switch on zero position.
- Set the temperature compensation control to the solution temperature.
- Adjust the zero adjustment knob so that the pointer in the meter reads exactly zero, when the electrodes are immersed in distilled water.
- Lift the electrodes from distilled water and wipe it dry using filter paper and dip them in standard buffer solution of known pH (4.0, 7.0 and 9.2).
- Change the function switches to particular pH range (0-7 or 7-14) and adjust the standardization knob till the pointer reads the correct pH value of the buffer solution.
- Do not disturb the zero knob adjustment.

pH measurement

- Weigh 20 g of air dry soil and transfer to a clean 100 ml beaker. Add 50 ml of distilled water.
- Using glass rod, stir the content intermittently and allow it to stand for half an hour.

Soil and Plant Analysis

- Wash the electrodes carefully with a jet of distilled water and wipe it dry with a piece of filter paper.
- Stir the soil suspension again just before taking the reading.
- Immerse the electrodes into the beaker containing soil water suspension and change the function switch to the particular pH range.
- Record the meter reading.

Electrical conductivity (EC)

The electrical conductivity (EC) measurement gives the total amount of soluble salts present in the soil and is expressed as milli mhos cm^{-1} or dS m^{-1} .

Principle

As the amount of the soluble salts in a solution increases the electrical conductivity also increases. This electrical conductivity is measured in terms of the resistance offered to the flow of current using a conductivity bridge.

It is known that solutions offer some resistance to the passage of electric current through them, depending upon the concentration of salts present. Hence EC is measured in terms of electrical resistance between parallel electrodes immersed in the soil suspension of water. In such a system, the solution between the electrodes becomes the electrical conductor to which the physical laws relating to resistance are applicable. The electrical resistance "R" is directly proportional to the distance "L" between the electrodes and inversely proportional to the cross sectional area "A" of the conductor.

Hence $R = L / A$ or $R = r \times L / A$

Where r = proportionality constant known as electrical resistivity

If $L = 1 \text{ cm}$ and $A = 1 \text{ cm}^2$ then $R = r$.

Where, r is called specific resistivity. Hence specific resistance is the resistance of a conductor 1 cm in length and 1 cm^2 in area.

Higher the salt content, higher the passage of current and lesser the resistance to the flow of the current. Hence the reciprocal of specific resistivity is called as specific conductivity. Therefore specific conductivity is defined as the conductivity of a solution enclosed in a cell whose electrodes are exactly 1 cm and possess a surface area of 1 cm^2 . The resistance is expressed as ohms cm^{-1} and the conductivity is expressed in reciprocal ohms or mhos per cm. It is not possible to make a conductivity bridge having electrodes 1 sq.cm. in area and place exactly 1 cm apart. Hence, the factor called the cell constant is determined for the given cell. Modern conductivity meters are calibrated to read directly the electrical conductance with given cell.

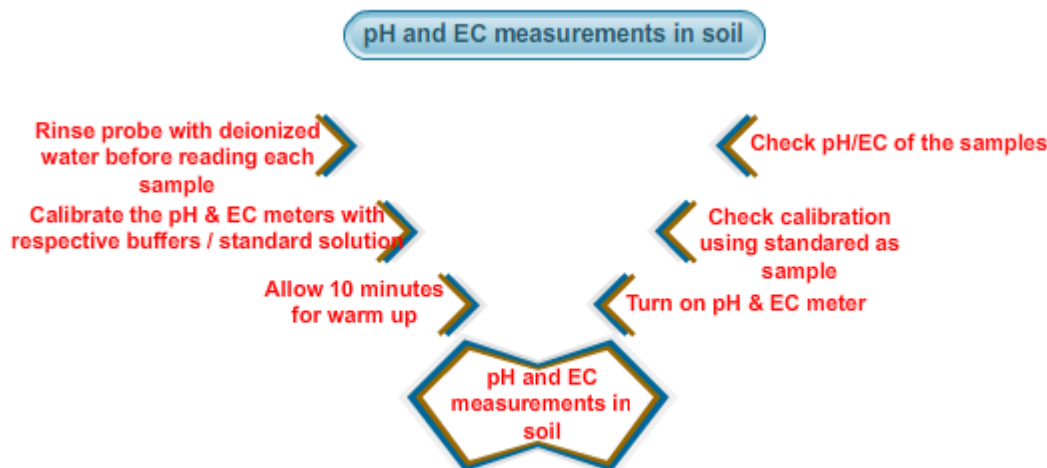
Materials required

i) Conductivity bridge ii) 100 ml beaker iii) Glass rod iv) 0.01 N KCl solution and v) Saturated CaSO_4 solution.

Procedure

Soil and Plant Analysis

- Switch on the conductivity bridge and wait for 10 minutes.
- Check the instrument, with saturated CaSO_4 solution and 0.01 N KCl solutions.
- The EC of saturated CaSO_4 and 0.01 N KCl solutions should be 2.2 and 1.41 dSm^{-1} respectively.
- Use the same soil water suspension used for measuring pH for the determination of EC.
- Stir the contents and allow the soil to settle for 15 minutes. Wash the electrodes carefully and immerse them into soil solution. Adjust the temperature correction.
- Adjust the meter knob until the magic eye of the null indicator is at the widest in width.
- The readings on the scale at this position indicate the electrical conductivity.
- Multiply this by the cell constant (noted on the cell itself) to get specific conductivity.



Oxidation-reduction potential or Redox potential

Redox potential (E_h) is otherwise called oxidation reduction reaction. Oxidation is the addition of oxygen or removal of hydrogen. Reduction is the addition of hydrogen or removal of oxygen.

In oxidation process, energy is released, electron is donated, or loss of electrons occurs. In reduction energy is accepted or acceptance of electrons or gain of electrons. This is also called as electron acceptance process. The compound, which donates electron or hydrogen, is called hydrogen donor or electron donor. The compound, which that accepts electron is called electron acceptor.

A substance is said to be oxidized when it loses its electron or when it acts as a hydrogen donor and a substance is said to be reduced when it gains electron or when it

act as hydrogen acceptor. In any chemical reaction every oxidation or loss of electron is accompanied by reduction or gain of electron. This system is called electron transfer system. The oxidation–reduction is also called coupled hydrogenation or hydrogenation process.

Redox potential is defined as “the capacity or potentiality of a compound either to oxidize or to reduce a substance or compound and this is expressed by electron unit called mV.

In soil system, soil organic matter provides the energy for release of electron.

Higher oxidation – positive (+) volt

Higher reduction – negative (-) volt

The redox potential is denoted by the symbol Eh

Where E denotes energy

$h = \text{Poise (stability of the system)}$

Eh is one of the physicochemical characters of soil used to determine whether the soil is submerged or aerated. When the soil is oxidized or aerated then the Eh is +ve. Soil in reduced condition then Eh is -ve.

Materials required:

1.Redox electrode

2.100 ml beaker

Procedure:

Soil and Plant Analysis

- Calibration procedure for relative mV measurement: Relative mV measurement calibration is normally used in ISE measurement. Where it is common to use the lowest concentration mV value as the base value for measurements. All subsequent measurement will then be based on that reference value.
- Press the mode key to enter the relative mV. The primary display shows absolute mV reading and the secondary display shows the temperature.
- Press CAL key to activate calibration mode. The CAL indicator will display on the LCD
- Adjust the base value required (182 mV) by using up and down keys.
- Press CON key to confirm the calibration. The CON indicator will flash for one second and will disappear. On disappearing the LCD will display zero mV reading.
- Now the meter is calibrated for relative mV measurement.
- Now insert the electrode into a beaker containing soil
- Press the CAL MEAS key so that the meter will return to the measurement mode. In this primary mode displays mV reading.

The display value is calculated as follows

Displayed value = Absolute mV readings - Relative mV base value



Lesson- 10

Principle and functioning of UV Spectrophotometer and Flame Photometer

UV Spectrophotometer

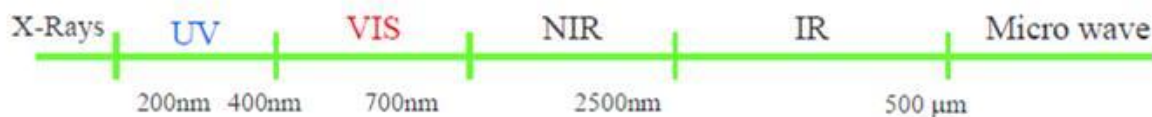
Ultraviolet and visible spectrometers have been in general use for the last 35 years and over this period have become the most important analytical instrument in the modern day laboratory. In many applications other techniques could be employed but none rival UV-Visible spectrometry for its simplicity, versatility, speed, accuracy and cost-effectiveness.

For convenience of reference, the Joint committee on Nomenclature in Applied Spectroscopy has set definitions of the various spectral regions as given below:

Region	Wavelength (nm)
Far ultraviolet	10 – 200
Near ultraviolet	200 -380
Visible	380 -780
Near infrared	780 – 3000
Middle infrared	3000 – 30,000
Far infrared	30,000 – 300,000
Microwave	300,000 – 1,000,000,000

The human eye is only sensitive to a tiny proportion of the total electromagnetic spectrum between approximately 380 and 780 nm and within this area we perceive the colors of the rainbow from violet through to red. If the full electromagnetic spectrum shown in Figure below was redrawn on a linear scale and the length of one centimeter represented the visible region, then the boundary between radio and microwaves would have to be drawn approximately 25 kilometers away.

◆ Electromagnetic Spectrum



A molecule or ion will exhibit absorption in the visible or ultraviolet region when radiation causes an electronic transition within its structure. Thus, the absorption of light by a sample in the ultraviolet or visible region is accompanied by a change in the electronic state of the molecules in the sample. The energy supplied by the light will promote electrons from their ground state orbital's to higher energy, excited state orbitals or antibonding orbital's.

Relationship between light absorption and color

Color absorbed	Colour observed	Absorbed radiation (nm)
Violet	Yellow-green	400-435
Blue	Yellow	435-480
Green-blue	Orange	480-490
Blue-green	Red	490-500
Green	Purple	500-560
Yellow-green	Violet	560-580
Yellow	Blue	580-595
Orange	Green-blue	595-605
Red	Blue-green	605-750

Concepts

A spectrophotometer is employed to measure the amount of light that a sample absorbs. The instrument operates by passing a beam of light through a sample and measuring the intensity of light reaching a detector.

The beam of light consists of a stream of photons is emitted continuously. When a photon encounters an analyte molecule (the analyte is the molecule being studied), there is a chance the analyte will absorb the photon. This absorption reduces the number of photons in the beam of light, thereby reducing the intensity of the light beam. Hence the intensity of the light reaching the detector is less than the intensity emitted by the light source.

Basic principle

Spectrophotometer is working based on the principle of beer-lamberts law. The processes concerned in absorption spectrometry are absorption and transmission. Usually the conditions under which the sample is examined are chosen to keep reflection, scatter and fluorescence to a minimum. In the ultraviolet and visible regions of the electromagnetic spectrum, the bands observed are usually not specific enough to allow a positive identification of an unknown sample, although this data may be used to confirm its nature deduced from its infrared spectrum or by other techniques. Ultraviolet and visible spectrometry is almost entirely used for quantitative analysis; that is, the estimation of the amount of a compound known to be present in the sample. The sample is usually examined in solution.

The Beer-Lambert Law

The Beer-Lambert Law states that the concentration of a substance in solution is directly proportional to the 'absorbance', A , of the solution.

Absorbance $A = \text{constant} \times \text{concentration} \times \text{cell length}$

The law is only true for monochromatic light that is light of a single wavelength or narrow band of wavelengths, and provided that the physical or chemical state of the substance does not change with concentration.

When monochromatic radiation passes through a homogeneous solution in a cell, the intensity of the emitted radiation depends upon the thickness (l) and the concentration (C) of the solution. I_0 is the intensity of the incident radiation and I is the intensity of the transmitted radiation. The ratio I/I_0 is called transmittance.

This is sometimes expressed as a percentage and referred to as % transmittance.

Mathematically, absorbance is related to percentage transmittance T by the expression:

Soil and Plant Analysis

$$A = \log_{10} (I_0/I) = \log_{10} (100/T) = kcL$$

Where L is the length of the radiation path through the sample, c is the concentration of absorbing molecules in that path, and k is the extinction coefficient - a constant dependent only on the nature of the molecule and the wavelength of the radiation.

Now, in the example above, the transmittance of our sample fell from 75 to 56.25% when the concentration doubled. What happens to the absorbance in the same circumstance?

$$A = \log_{10} (100/T) = \log_{10} (100) - \log_{10} (T) = 2 - \log_{10} (T)$$

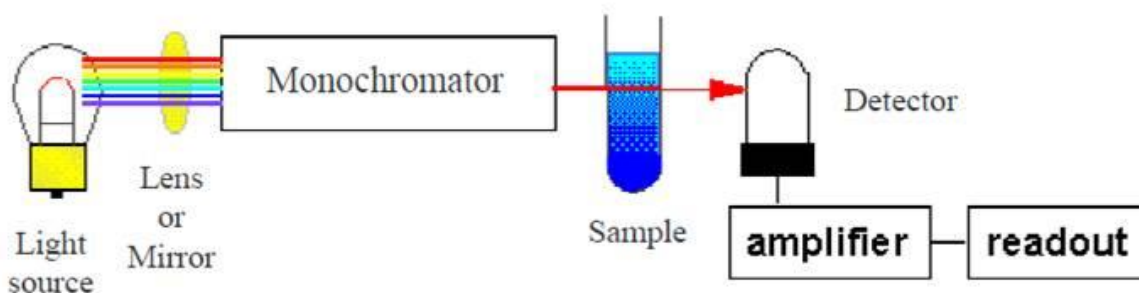
$$\text{When } T = 75\%, A = 2 - 1.875 = 0.125$$

$$\text{When } T = 56.25\% A = 2 - 1.750 = 0.250$$

Quite clearly as the absorbance doubles for twice the concentration, it is far more convenient to work in absorbance than transmittance for the purposes of quantitative analysis.

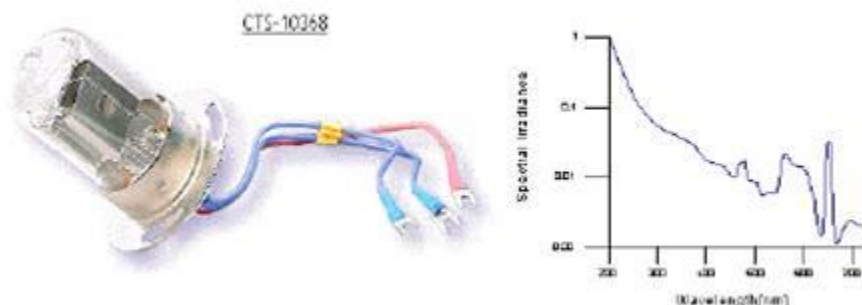
It is useful to remember that 0%T = ∞ A, 0.1% = 3.0A, 1.0%T = 2.0A, 10%T = 1.0A and 100% = 0A

Structure of UV-Vis Spectrophotometer

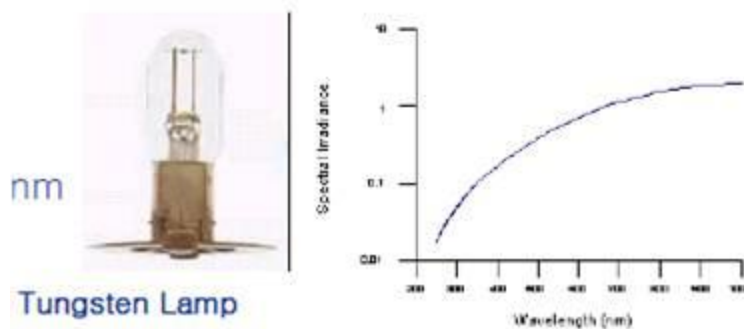


Light source

1. Deuterium Arc Lamp: UV region - WL range 190~420 nm

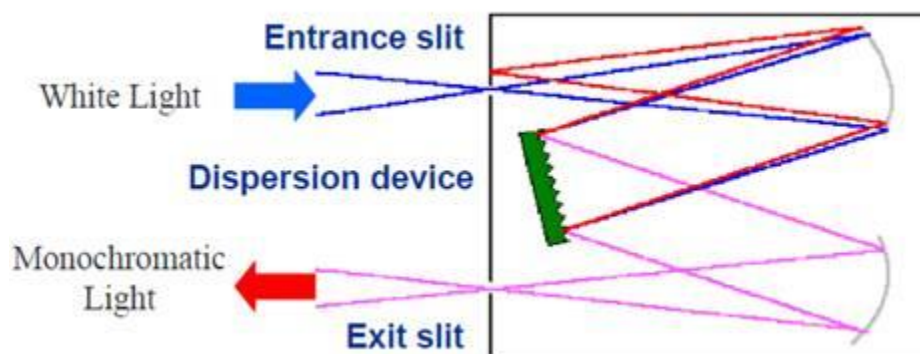


2. Tungsten lamp: WL range: part of the UV and a whole of the visible region- 350 ~ 2500 nm



3. Xenon lamp: WL range 190~800 nm
Monochromator

Accepts polychromatic input light from a lamp and outputs monochromatic light
Components : Entrance cell, Dispersion device, Exit slip



Experimental Procedure

The following simulation illustrates the procedures for making spectrophotometric measurements.

First, the intensity of light (I_0) passing through a blank is measured. The intensity is the number of photons per second. The blank is a solution that is identical to the sample solution except that the blank does not contain the solute that absorbs light. This measurement is necessary, because the cell itself scatters some of the light.

Second, the intensity of light (I) passing through the sample solution is measured. (In practice, instruments measure the power rather than the intensity of the light. The power is the energy per second, which is the product of the intensity (photons per second) and the energy per photon.)

Third, the experimental data is used to calculate two quantities: the transmittance (T) and the absorbance (A).

$$T = \frac{I}{I_0}$$
$$A = -\log_{10} T$$

The transmittance is simply the fraction of light in the original beam that passes through the sample and reaches the detector.

The remainder of the light, $1 - T$, is the fraction of the light absorbed by the sample. (Do not confuse the transmittance with the temperature, which often is given the symbol T .)

In most applications, one wishes to relate the amount of light absorbed to the concentration of the absorbing molecule.

It turns out that the absorbance rather than the transmittance is most useful for this purpose.

If no light is absorbed, the absorbance is zero (100% transmittance).

Each unit in absorbance corresponds with an order of magnitude in the fraction of light transmitted.

For $A = 1$, 10% of the light is transmitted ($T = 0.10$) and 90% is absorbed by the sample.

For $A = 2$, 1% of the light is transmitted and 99% is absorbed. For $A = 3$, 0.1% of the light is transmitted and 99.9% is absorbed.

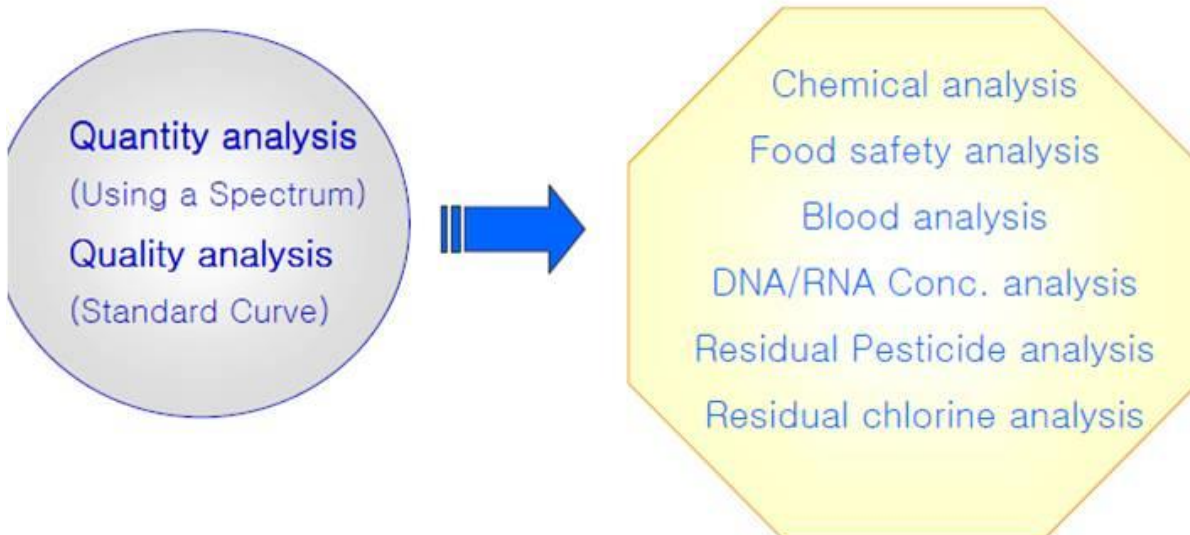
Using the simulation below, perform the following steps:

- Measure the intensity of light passing through the blank.
- Measure the intensity of light passing through the sample.
- Calculate the transmittance.
- Calculate the absorbance.

Limitation of Beer-Lamberts law

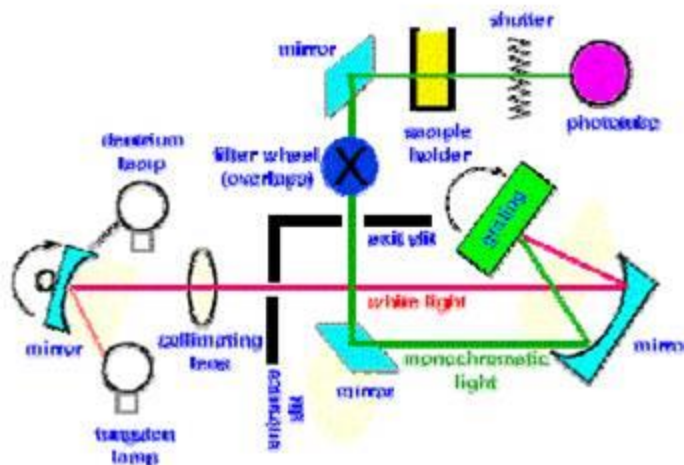
- Deviations in absorptivity coefficients - at high concentrations (>0.01 M) due to electrostatic interactions between molecules in close proximity
- Scattering of light- due to particulates in the sample
- Fluorescence or Phosphorescence of the sample
- Changes in refractive index at high analysis concentration
- Shifts in chemical equilibria as a function of concentration
- Stray light

Application of UV/VIS Spectrophotometer

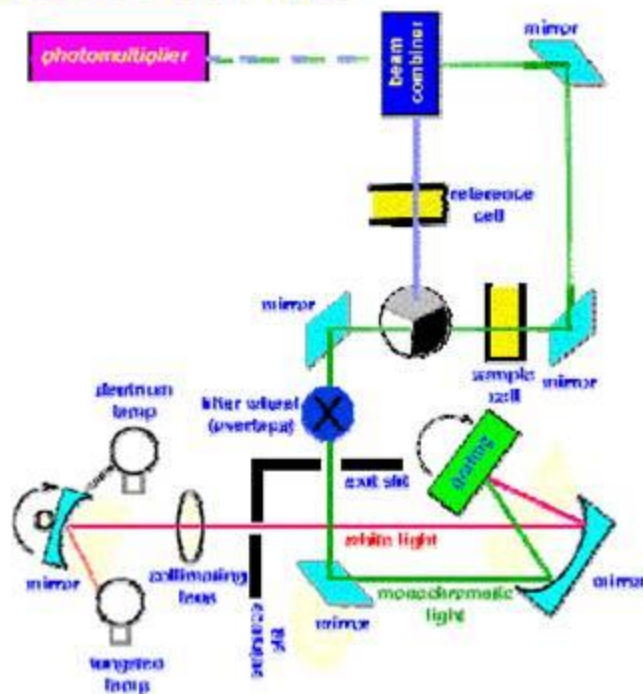


Types of UV spectrophotometer

• Single Beam Type



• Double Beam Type



FLAME PHOTOMETRY

- Flame photometry (more accurately called flame atomic emission spectrometry) is a branch of atomic spectroscopy in which the species examined in the spectrometer are in the form of atoms.
- The other two branches of atomic spectroscopy are atomic absorption spectrophotometry (AAS, Atomic Absorption Spectrophotometry) and inductively coupled plasma-atomic emission spectrometry (ICP-AES, a relatively new and very expensive technique not used in Standardbase experiments).
- In all cases the atoms under investigation are excited by light. Absorption techniques measure the absorbance of light due to the electrons going to a higher energy level.
- Emission techniques measure the intensity of light that is emitted as electrons return to the lower energy levels.
- Flame photometry is suitable for qualitative and quantitative determination of several cations, especially for metals that are easily excited to higher energy levels at a relatively low flame temperature (mainly Na, K, Rb, Cs, Ca, Ba, Cu).

Principles of operation

Flame photometry relies upon the fact that the compounds of the alkali and alkaline earth metals can be thermally dissociated in a flame and that some of the atoms produced

will be further excited to a higher energy level. When these atoms return to the ground state they emit radiation, which lies mainly in the visible region of the spectrum. Each element will emit radiation at a wavelength specific for that element. The table below gives details of the measurable atomic flame emissions of the alkali and alkaline earth metals in terms of the emission wavelength and the colour produced.

Element Emission Wavelength (nm) & Flame Colour

Element	Emission Wavelength (nm)	Flame Colour
Sodium (Na)	589	Yellow
Potassium (K)	766	Violet
Barium (Ba)	554	Lime Green
Calcium (Ca)	622*	Orange
Lithium (Li)	670	Red

*Note: Calcium is measured by using the calcium hydroxide band emission at 622nm as the Calcium main atomic emission occurs at 423nm.

Over certain ranges of concentration the intensity of the emission is directly proportional to the number of atoms returning to the ground state. This is in turn proportional to the absolute quantity of the species volatilized in the flame, i.e. light emitted is proportional to sample concentration.

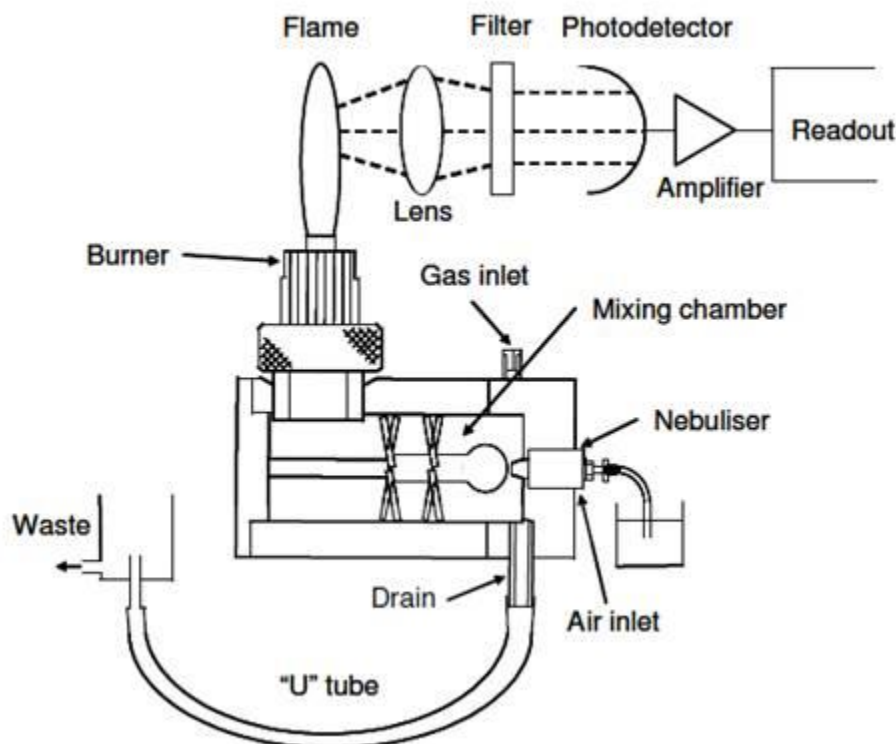
It can be seen that if the light emitted by the element at the characteristic wavelength is isolated by an optical filter and the intensity of that light measured by a photo-detector, then an electrical signal can be obtained proportional to sample concentration. Such an electrical signal can be processed and the readout obtained in an analogue or digital form.

A simple flame photometer consists of the following basic components:

1. The burner: a flame that can be maintained in a constant form and at a constant temperature.
2. Nebuliser and mixing chamber: a means of transporting a homogeneous solution into the flame at a steady rate.
3. Simple colour filters (interference type): a means of isolating light of the wavelength to be measured from that of extraneous emissions.
4. Photo-detector: a means of measuring the intensity of radiation emitted by the flame

Working principle

Schematic diagram of a flame photometer



When a liquid sample containing a metallic salt solution is introduced into a flame, the processes involved in flame photometry are complex, but the Following is a simplified version of the events:

- The solvent is vaporized, leaving particles of the solid salt.

Soil and Plant Analysis

- The salt is vaporized or converted into the gaseous state.
- A part or all of the gaseous molecules are progressively dissociated to give free neutral atoms or radicals. These neutral atoms are excited by the thermal energy of the flame. The excited atoms, which are unstable, quickly emit photons and returns to lower energy state, eventually reaching the unexcited state. The measurement of the emitted photons, i.e., radiation forms the basis of flame photometry.

Liquid sample → containing element aspirated into a flame	Formation of the → liquid droplets	Evaporation of droplets resulting in the formation of residue
Wavelength and ← intensity of emitted radiation measured by flame photometry	Formation of excited ← atoms and emission of radiation from atoms	Decomposition of residue into neutral atoms

Factors that Influence the Intensity of Emitted Radiation in a Flame Photometer

A number of factors will influence the intensity of light emission from a given solution.

Some of these are as follows:

Viscosity

- The addition of a substance which increases the viscosity of the solution (e.g., sucrose) decreases the intensity of light emission. This decrease results in due to a reduction in the efficiency of atomization.

Presence of Acids

- When an acid is present in the sample solution, this decrease the light intensity. This decrease arises due to the disturbance of the initial dissociation equilibrium.

Presence of Other Metals

- If other metals are present, these also alter the intensity of emitted radiation. In order to remove this defect, special filters are used which will absorb radiation due to the element, which is to be estimated in the sample solution.

Advantages:

1. Their atoms reach the excited state at a temperature lower than that at which most other elements are excited.
2. Their characteristic wavelengths are easily isolated from those of most other elements due to wide spectral separation.
3. The analysis of Na, K, Li, Ba and Ca are typically determined at low temperatures, i.e. 1500- 2000°C, therefore suitable fuel mixtures are propane/air, butane/air and natural gas/air.

Disadvantages

Low temperature makes this method susceptible to, particularly, interference and the stability (or lack thereof) of the flame and aspiration conditions.

Many different experimental variables affect the intensity of light emitted from the flame. Fuel and oxidant flow rates and purity, aspiration rates, solution viscosity, concomitants in the samples, etc. affect these.

Therefore, careful and frequent calibration is necessary for good results and it is very important to measure the emission from the standard and unknown solutions under conditions that are as nearly identical as possible.



Lesson- 11

Principle and functioning of Atomic Absorption Spectrophotometer

Principle

The sample is vaporized by aspiration of solution into a flame or evaporation from electrically heated surface (temperature range: 1800 – 31000 K). At this condition where the individual atoms co-exist, a beam of light is passed through them. The atoms will absorb in the visible and ultraviolet region resulting in changes in electronic structure (excited state). So, the resultant light beam coming out of the sample will be missing the light in the corresponding wavelength, which is a measure of the characteristics of the sample.

Atomic Absorption Spectrophotometry is designed to determine the amount (concentration) of an object element in a sample, utilizing the phenomenon that the atoms in the ground state absorb the light of characteristic wavelength passing through an atomic vapor layer of the element.

Instrumentation

1. Hollow-cathode lamp (light source or radiation emitting source),
2. Atomizer unit (Flame burner and electrically heated furnace-graphite furnace),
3. Monochromator (to select the analysis wavelength of the target element)
4. Detector (photomultiplier) and Recorder.

The hollow cathode lamp for the light source consists of a hollow cathode and an anode enclosed in a glass (quartz) tube and neon or argon gas is filled at around 10 Torr in pressure in it. The cathode is made of the element to be measured or its alloy, so it emits the light its wavelength is equal to that absorbed by the atoms of the sample.

Resonance lines of common elements for AAS

S.NO.	Elements	WL of absorption
1.	Zinc (Zn)	213.90
2.	Copper (Cu)	324.80
3.	Iron (Fe)	248.30
4.	Manganese (Mn)	279.50

5.	Calcium (Ca)	357.90
6.	Magnesium (Mg)	285.20
7.	Potassium (K)	766.50
8.	Sodium (Na)	589.00
9.	Cadmium (Cd)	228.80
10.	Nickel (Ni)	232.00
11.	Chromium (Cr)	357.90
12.	Lead (Pb)	283.30
13.	Barium (Ba)	553.60
14.	Gold (Ag) check	242.80

When a solution containing metallic species is introduced into a flame, the vapour of metallic species will be obtained. Some of the metal atoms may be raised to an energy level sufficiently high to emit the characteristic radiation of the metal—a phenomenon that is utilized in the familiar technique of emission flame photometry. But a large percentage of the metal atoms will remain in the non-emitting ground state. These ground state atoms of a particular element are receptive of light radiation of their own specific resonance wave-length (in general, the same wavelength as they would emit if excited). Thus, when a light of this wavelength is allowed to pass through a flame having atoms of the metallic species, part of that light will be absorbed and the absorption will be proportional to the density of the atoms in the flame. Thus, in atomic absorption spectroscopy, one determines the amount of light absorbed. Once this value of absorption is known, the concentration of the metallic element can be known because the absorption is proportional to the density of the atoms in the flame. Mathematically, the total amount of light absorbed may be given by the expression as follows:

$$A_{\nu} = \frac{4\pi^2 N e^2 f}{m c^2} \rho_{\nu} l$$

... (1.1)

where e is the charge on the electron of mass m , c the speed of light, N the total number of atoms that can absorb at frequency ν in the light path and f the oscillator strength or ability for each

atom to absorb at frequency, ν . As π , e , m and c are constants, equation (1.1) can be simplified to the following expression

$$\text{Total amount of height absorbed} = \text{constant} \times N \times f \dots (1.2)$$

From expression (1.2), it follows that

Firstly, there is no term involving the wavelength (or frequency) of absorption other than the indication of the actual absorption wavelength.

Secondly, there is no term involving the temperature.

From above, it follows that absorption by atom is independent of the wavelength of absorption and the temperature of the atoms. These two features provide atomic absorption spectroscopy distinct advantages over flame emission spectroscopy.

Applications

- This is the most widely used technique for the quantitative determination of metals at trace levels (0.1 to 100ppm), which present in various materials.
- It utilizes Beer - Lambert Law for the analysis and a standard curve is obtained by plotting absorbance vs concentration of the samples taken.
- The usual procedure is to prepare a series of standard solutions over a concentration range suitable for the sample to be analyzed.
- Then, the standards and the samples are separately aspirated into the flame, and the absorbances are read from the instrument. The plot will give the useful linear range and the concentrations of the samples can be found out from the plot.

Disadvantages

- Sample must be in solution or at least volatile.
- Individual source lamp.

- Though multielement lamp sources are available nowadays, only limited combinations are there due to metallurgical properties or spectral limitations.
- Use of multielement lamp results in poorer signal/noise ratio which can influence the precision of analyses and detection limit.

Functions

Flame atomic absorption spectroscopy (AAS) is the most used of atomic methods. The principle mentioned above can be applied to light absorption of "Free atoms". A "Free atom" means an atom not combined with other atoms. However, elements in the sample to be analyzed are not in the Free State, and are combined with other elements invariably to make a so-called molecule. The combination must be cut off by some means to free the atoms. This is called atomization. The most popular method of atomization is dissociation by heat - samples are heated to a high temperature so that molecules are converted into free atoms. This method is classified into the flame method, in which a chemical flame is used as the heat source; and an electrothermal atomization method, in which a very small electric furnace is used. The comparison of the flame atomization method and electrothermal atomization method is shown in the following table

<i>Parameters</i>	<i>flame atomization</i>	<i>electrothermal atomization</i>
Sensitivity	ppm level in the solution	ppb level in the solution
Sample Volume	about 1mL for one analysis	5 - 50 μ L for one analysis
Atomizing efficiency	about 10%	More than 90%
Shape of signal	plateau shape	Peak shape
Repeatability	0.5 - 1.0% in R.S.D.	2.0 - 5.0% in R.S.D.
Matrix effect	Small	large
Time for analysis	10 - 30 sec. For one sample	2 - 5 min. for one sample

Working principle

Radiation from a line source is focused on the atomic vapor in a flame or an electrothermal atomizer. The attenuated source radiation then enters a monochromator, which isolates the line of interest. Next the radiant power from the source, attenuated by absorption, is measured by the photomultiplier tube (PMT). The signal is then processed and directed to a computer system for output.

For the light source, a hollow cathode lamp and a discharge lamp are mainly used. To the sample-atomizer, the flame type, electrothermal type, and the cold-vapor type are applied. The flame type is composed of a burner and a gas-flow regulator, the electrothermal type is composed of an electric furnace and a power source, and the cold-vapor type is composed of a mercury generator by chemical reduction-vaporization and thermal reduction-vaporization and an absorption cell.

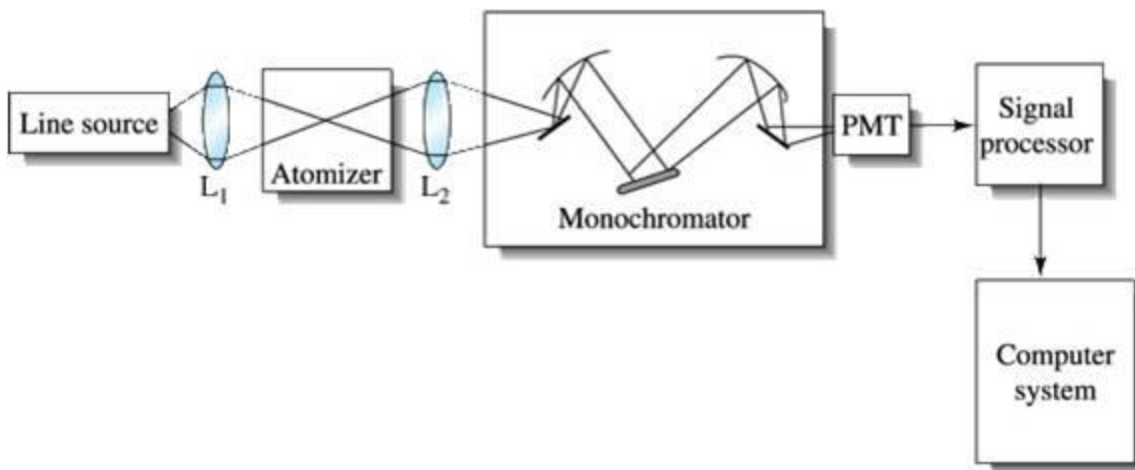
Types of AAS

There are two basic types of atomic absorption instruments: singlebeam and double-beam.

Single Beam

The light source (hollow cathode lamp or electrodeless discharge lamp) emits a spectrum specific to the element of which it is made, which is focused through the sample cell into the monochromator. The light source must be electronically modulated or mechanically chopped to differentiate between the light from the source and the emission from the sample cell. The monochromator disperses the light and the specific wavelength of light isolated passes to the detector, which is usually a photomultiplier tube. An electrical current is produced depending on the light intensity and processed by the instrument electronics. The electronics will measure the amount of light attenuation in the sample cell and convert those readings to the actual sample concentration. With single-beam systems, a short warmup period is required to allow the source lamp to stabilize.

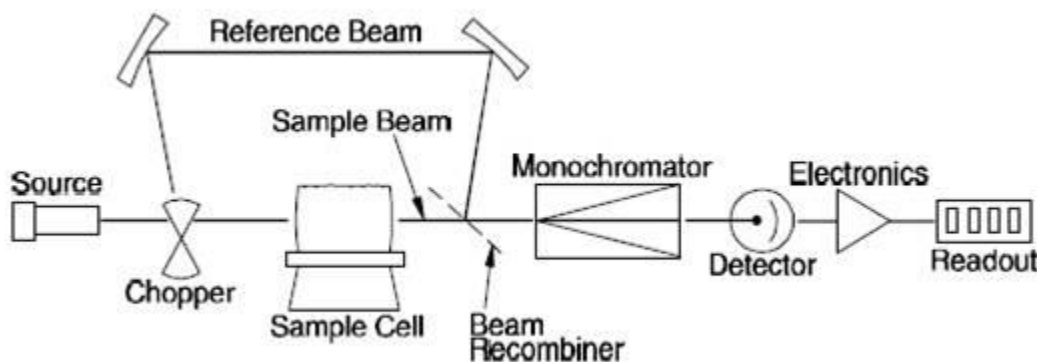
Block diagram of a single-beam atomic absorption spectrometer



Double Beam

The light from the source lamp is divided into a sample beam, which is focused through the sample cell, and a reference beam, which is directed around the sample cell. In a double-beam system, the readout represents the ratio of the sample and reference beams. Therefore, fluctuations in source intensity do not become fluctuations in instrument readout, and stability is enhanced. Generally, analyses can be performed immediately with no lamp warm-up required.

Block diagram of a Double-beam atomic absorption spectrometer



Accessory Sampling Techniques

Flame atomic absorption is a widely used technique that offers many advantages. However, there are analytical situations in which flame methodology is limited in sensitivity or sampling flexibility. To address such requirements, there are several accessories available that are briefly described below.

Graphite Furnace Systems

The graphite furnace, which requires only a few microliters of sample, is ideal for ultra-trace determination of more than 60 elements. It can provide detection limits 1000 times lower than those of conventional flame techniques. The energy required for atomization is supplied by applying a high electrical current through a graphite tube where the sample has been placed. The furnace is located in the sample compartment so that light from the spectral lamp passes through the graphite tube. The atomic vapor generated when the furnace is fired absorbs light from the lamp. A peak-shaped signal is produced and peak area is measured. A programmable power supply is available which provides precise control of temperature programs and storage of programs for later use.

Mercury/hydride system

The mercury/hydride system is used for the high-sensitivity determination of mercury and the metallic hydride-forming elements such as As, Se, Sb, Te, Bi, and Sn. Mercury is determined by the cold vapor technique after reduction with stannous chloride or sodium borohydride.

Flow injection systems (FIAS)

Several flow injection systems (FIAS) are available to provide a wide variety of automated sample-handling capabilities.

Flow Injection Mercury System (FIMS)

The Flow Injection Mercury System (FIMS) is a compact dedicated system for the determination of mercury.



Lesson- 12

Genesis, Characterization and Management of Saline-Sodic Soils

INTRODUCTION

There are four major tracts where salt affected soils are commonly met within India.

These are

1. The Semi-arid Indo-Gangetic alluvial tracts (mainly in Punjab, Haryana, Uttar Pradesh and a part of Bihar)
2. The arid tracts of Rajasthan and Gujarat.
3. The arid and semi arid tracts of southern states, particularly of the irrigated rigor (Vertisols) soils.
4. The coastal alluvium

Earlier it was estimated that about 7 million hectares of land have been affected by salinity/sodicity conditions in India. The area under these soils increased and reached to the level 10 million hectares at present.

Classification of saline sodic soils

Based on pH, electrical conductivity (EC) and Exchangeable sodium percentage (ESP = Exchangeable Na⁺ x 100) saline -sodic soils are classified as follows.

CEC

	EC (dsm-1)	ESP	pH
Saline	> 4.0	< 15	< 8.5
Sodic	< 4.0	> 15	> 8.5
Saline - sodic	> 4.0	>15	< 8.5 or > 8.5

Saline soils / white alkali / solonchak

Soil and Plant Analysis

Soils with high amount of soluble salts having $EC > 4.0 \text{ dsm}^{-1}$ and white encrustations are seen on the surface. Hence it is called as white alkali.

Brown alkali

Saline soils with high proportion of nitrate salts.

Genesis of saline – sodic soils

Parent material

Soils formed from rocks having high proportion of bases are become saline / sodic in nature.

eg. Basalt, Sand stone etc.

Low rainfall

One of the important reason for the development of saline-sodic soils is insufficient water to remove bases from soil horizon and thereby accumulation of salts in soil. This is more common in semi arid and arid regions where the rainfall is usually low.

High Evaporation

Water along with salts reaches the surface from sub surface of the soil by capillary raise due to high evaporation in arid and semi arid regions. This results in accumulation of salt at surface of the soil while water alone moves to atmosphere.

Poor drainage

Water logged salinity / sodicity is a common seen in low-lying area of inlands particularly in high clay soils. Improper drainage leads to accumulation of salts at surface horizon and becomes reason for entry of sodium in clay complex.

Poor quality irrigation waters

Continuous use of poor quality saline / sodic water for cultivation accumulates salts / sodium in the soils.

High water table

High water table at alluvial plains and other areas leads to improper drainage, which leads to accumulation of salts in soils.

Sea water intrusion

In coastal regions seawater intrudes into land and pollutes the soil as well as ground water of that locality.

Base forming fertilizers

Continuous application of base forming fertilizers for cultivation is also causes soil salinity / sodicity. eg. NaNO_3

SALINE SOILS

Soils having higher proportion of soluble salts affect adversely the growth of plants. The salt level in saline soils exceeds a limit of 4.0 dSm^{-1} . Mostly these soils are dominant with chlorides and sulphates salts. These salts are neutral salts and hence the pH of these soils may not be more than 8.5. Saline soils are formed through a soil forming process called salinization in semi arid and arid zones. Salinization refers to accumulation of soluble salts in the soil surface horizons.

Effects of soil salinity

The characteristics feature of saline soil is white encrustation on surface of soils due to evaporation of water to atmosphere leaving the salts on surface of soils. Presence of salts leads to alteration of osmotic potential of the soil solution. Consequently water intake by plants restricted and there by nutrients uptake by plants are also reduced. In these soils due to high salt levels microbial activity is reduced consequently slow decomposition and low nutrient availability particularly nitrogen and sulphur. Due to osmotic potential alteration water from plants cells moves to soil and plants are affected due to dehydration. As a result drying of leaves and finally death of plants occur. Apart from above effects specific ion effects on plants are also seen due to toxicity of ions like chloride, sulphate etc.

Reclamation

All saline soils can be reclaimed easily if good quality water is available. Since the salts in this soils are soluble in nature using quality water they can be solubilized and leached off from the field. In the absence of good quality water it becomes necessary to manage saline soils for better growth of plants.

Management of saline soils

1. Crop management

Growing crops that are tolerant high level soil salinity e.g.: Cotton, Ragi, Barley, sugar beat, Beet root, curry leaf, Bermuda grass, saline grass, spinach etc. Crops that are tolerant to soil salinity at medium level are paddy, wheat, onion, maize, sunflower, castor, grape, pomegranate, tomato, cabbage and potato. Crops that are tolerant to low level of soil salinity are garden

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beans, Reddish, lime etc. Black gram, green grams are sensitive to soil salinity. Crops are to be chosen based on the soil salinity level.

Relative tolerance of crops to salinity

Plant species	Threshold salinity (dS m ⁻¹)
Field crops	
Cotton	7.7
Sugarbeet	7.0
Sorghum	6.8
Wheat	6.0
Soybean	5.0
Groundnut	3.2
Rice	3.0
Maize	1.7
Sugarcane	1.7
Vegetables	
Tomato	2.5
Cabbage	1.8
Potato	1.7
Onion	1.2
Carrot	1.0
Fruits	
Citrus	1.7

2. Soil / cultural management

Growing crops in raised beds will reduce accumulation of salt around root zone. Planting seedlings / sowing seeds on sloppy ridges decreases accumulation of salts around root zone.

Mulching soil prevents evaporation which reduces accumulation of salts due to capillary rise of water at surface of soils. Providing drainage in water logged areas also helps to reduce salt accumulation.

3. Fertilizer Management

Addition of extra dose of nitrogen to the tune of 20 – 25% of recommended level will compensate the low availability of N in these soils. Addition of organic manures like, FYM, compost, etc helps in reducing the ill effect of salinity due to release of organic acids produced during decomposition. Green manuring (sun hemp, Daincha, Kolingi) and / or green leaf

manuring also counteracts the effects of salinity.

4. Irrigation management

Proportional mixing of good quality (if available) water with saline water and then using for irrigation reduces effect of salinity. Alternate furrow irrigation favors growth of plant than flooding. Drip and sparkler irrigation systems aim to reduce the use of water which is favorable for growth of plant since salt accumulation also reduced with low usage of water.

All the above four management practices suitably integrated to reduce the soil salinity, which is favorable for better growth of plants and ultimately for better yields. Management of saline soils becomes essential and unavoidable particularly in areas where both soil as well as irrigation water are saline in nature.

Sodic soils

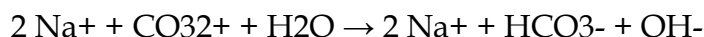
Sodic soils are having high proportion of sodium at exchange complex. The sodium ion at exchange complex usually exceeds 15 percentage in these soils. These soils also have high proportion of precipitated insoluble carbonates and bicarbonates and hence the pH always more than 8.5. On contrary degraded sodic soils have low pH at surface but exchangeable sodium percentage is more than 15 and they do not have precipitated CaCO_3 . Sodic soils are formed due to the soil forming process of alkalization (accumulation sodium in soils) while sodic soils / degraded alkali (sodic) formed by the process called solidization.

Effect of soil sodicity

Since these soils have high amount of CO_3 and HCO_3 and high pH, Carbonate, bicarbonate and OH (hydroxyl) ions injuries on plants are observed. High sodium in clay becomes reason for dispersed nature of clay under wet moisture regions.

Dispersed nature of the clay leads to soapy feeling of soils, stagnation of water, poor infiltration/ percolation and poor aeration. Sodic soils become hard mass during dry periods. These soils have poor workability both under wet and dry seasons.

Further hazardous effects of Na on plants are also seen. Sodium carbonate with water releases Na^+ , HCO_3^- and OH^- ions, which are harmful to growing plants.



High pH is also unfavorable for the growth of microorganisms.

Low microbial activity causes slow decomposition of organic matter and hence nutrient availability is also affected specifically nitrogen, sulphur etc.

Since these soils enriched with high Na at exchange complex, Ca and Mg availability are also less.

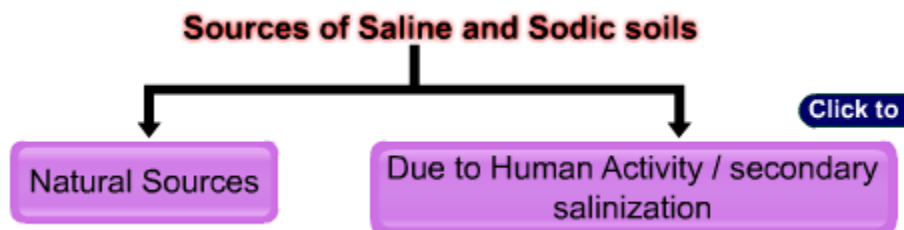
High pH becomes the reason for non-availability or less availability of Fe and Zn.

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Deficiency of Zn is common in this soils.

Phosphorus availability is also less due to conversion of phosphors into insoluble calcium and magnesium phosphates.

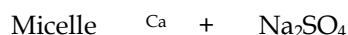
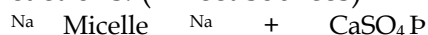
All the above effects on plants result in drying of plants in patches in a field. Under extreme conditions no plants are seen in these soils.



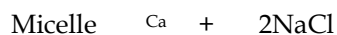
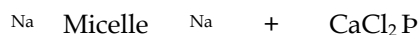
Materials

Gypsum, Calcium Chloride, Calcium Carbonates, Phospho gypsum etc are used for reclamation which are directly supply calcium as they have calcium in their composition. Among them gypsum is most commonly used. CaCO_3 is insoluble in nature which of no use in sodic soils (have already precipitated CaCO_3) but can be used in degraded sodic soils (do not have precipitated CaCO_3) since pH of this soils are low and favoring solubilization of CaCO_3 . Some of the indirect suppliers of Ca (elemental sulphur, sulphuric acid, iron sulphate) are also used for sodic soils. These materials on application solubilize precipitated CaCO_3 in sodic soils and releases Ca for reclamation (for exchange reaction). Since degraded sodic soils do not have precipitated CaCO_3 , use of these materials is not beneficial. Lime sulphur supply Ca both directly as well as indirectly.

Reactions: (Direct sources)



(leachable)

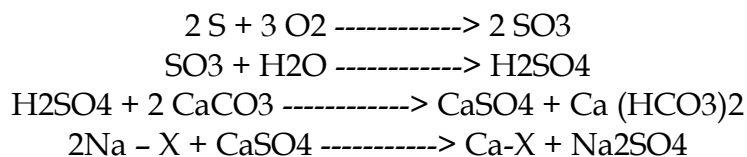


(leachable)

Indirect sources

Sulphur and iron sulphate are converted into sulphuric acid which dissolves native CaCO_3 . Thus Ca is made available for exchange reactions.

Sulphur - microbial oxidation



Relative tolerance of crops to sodicity

ESP (range*)	Crop
2-10	Deciduous fruits, nuts, citrus, avocado
10-15	Safflower, black gram, peas, lentil, pigeon pea
16-20	Chickpea, soybean

20-25	Clover, groundnut, cowpea, pearl millet
25-30	Linseed, garlic, cluster bean
30-50	Oats, mustard, cotton, wheat, tomatoes
50-60	Beets, barley, sesbania
60-70	Rice

*Relative yields are only 50% of the potential in respective sodicity ranges.

Relative tolerance of fruit trees to sodicity

Tolerance to sodicity	ESP	Trees
High	40-50	Ber, tamarind, sapota, wood apple, date palm
Medium	30-40	Pomegranate
Low	20-30	Guava, lemon, grape
Sensitive	20	Mango, jack fruit, banana

- Grasses suitable for sodic soils: Cynodon dactylon, Brachiaria mutica and Pai korai.
- Fodder species suitable for sodic soils: Medicago sativa, Trifolium aleandrum, Avena sativa, Medicago denticulate.
- Trees suitable for sodic soils: Azadirachta indica, Prosopis juliflora, Tamarind , Albizzia, Zizyphus sp., Acacia sp., and Cassia sp. etc.



Lesson- 13 Genesis, Characterization and Management of Acid Soils

INTRODUCTION

- Soil acidity refers to presence of higher concentration of H⁺ concentration in soil solution and at exchange sites. Soil acidity is a major problem in relation to plant growth and therefore acid soils are called as a problem soil. Acid soils are characterized by low soil pH, which varies from strongly acidic (4.5-5.5) to extremely acidic (<4.5) and with low base saturation.
- Soil acidity is of three kinds' viz., active acidity, exchangeable acidity and residual acidity. The hydrogen ions in the soil solution contribute to active acidity. It may be defined as the acidity developed due to concentration of H and Al ions in the soil solution. The concentration of hydrogen ion in soil solution due to active acidity is very small, implying that only a meager amount of lime would be required to neutralize active acidity. In spite of smaller concentration, active acidity is important since the plant root and the microbes around the rhizosphere are influenced by it.
- The concentration of exchangeable Al and H ions contribute to exchangeable acidity. It may be defined as the acidity developed due to adsorbed H⁺ and Al³⁺ ions on soil colloids.
- Aluminium hydroxyl ions and H and Al ions present in non - exchangeable form with organic matter and clay account for the residual acidity.

Total acidity = Active acidity + Exchangeable acidity + Residual acidity

Sources of soil acidity

Leaching due to heavy rainfall

Acid soils are common in all regions where rainfall or precipitation is high enough to leach appreciable amounts of exchangeable bases from the surface soils and relatively insoluble compounds of Al and Fe remains in soil. The nature of these compounds is acidic and its oxides and hydroxides react with water and release hydrogen ions in soil solution and make soil acidic. Besides, when the soluble bases are lost, the H⁺ ions of the carbonic acid and other acids developed in the soil replace the basic cations of the colloidal complex. As the soil gets gradually depletes of its exchangeable bases through constant leaching, it gets desaturated and becomes increasingly acid.



(Carbonic acid)



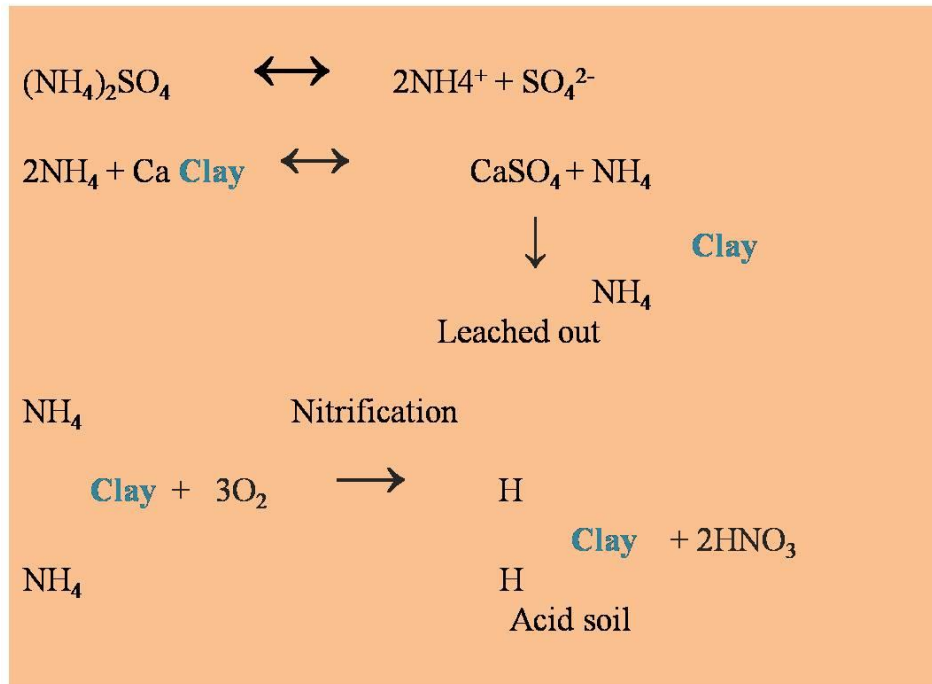
Calcite (Insoluble) readily soluble and leachable

Acidic parent material

Some soils have developed from parent materials which are acid such as granite and that may contribute to some extent soil acidity.

Acid forming fertilizers and soluble salts

The use of ammonium sulphate and ammonium nitrate increases soil acidity. Ammonium ions from ammonium sulphate when applied to the soil replace calcium ions from the exchange complex and the calcium sulphate is formed and finally leached out.



Besides, basic portion of ammonium sulphate is NH_4^+ and it undergoes biological transformation in the soil and form acid forming nitrate ions. Similarly, sulphur also produces acid forming sulphate ions through oxidation. Divalent cations of soluble salts usually have a

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greater effect on lowering soil pH than monovalent metal cations.

Humus and other organic acids

During organic matter decomposition, humus, organic acids and different acid salts may also be produced and also concentration of CO₂ increased. The increased concentration of CO₂, hydrolysis of acid salts and various organic acids increased the total acidity of soil.

Aluminosilicate minerals

At low pH values most of the Al is present as the hydrated Aluminium ions, which undergoes hydrolysis and release hydrogen ions in the soil solution.

Carbon dioxide

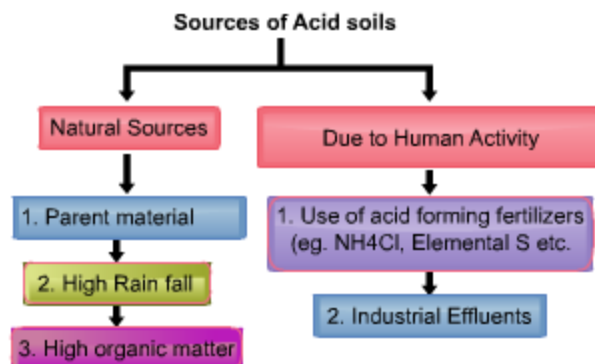
Soil containing high concentration of CO₂, the pH value of such soil will be low and the soil becomes acidic. Root activity and metabolism may also serve as sources of CO₂, which ultimately helps the soil to become acidic.

Hydrous oxides

These are mainly oxides of iron and aluminium. Under favourable conditions they undergo stepwise hydrolysis with the release of hydrogen ions in the soil solution and develop soil acidity.

Production constraints

- Increased solubility and toxicity of Al, Mn and Fe
- Deficiency of Ca and Mg,
- Reduced availability of P and Mo and
- Reduced microbial activity



Management of acid soils

Management of the acid soils should be directed towards enhanced crop productivity either through addition of amendments to correct the soil abnormalities or by manipulating the agronomic practices depending upon the climatic and edaphic conditions.

Soil amelioration

Lime has been recognized as an effective soil ameliorant as it reduces Al, Fe and Mn toxicity and increases base saturation, P and Mo availability of acid soils. Liming also increases atmospheric N fixation as well as N mineralization in acid soils through enhanced microbial activity.

Liming materials

Source of lime material is an important aspect of acid soil management and the economics of application of different sources need to be given due importance.

Commercial limestone and dolomite limestone are the most widely used amendments.

Carbonates, oxides and hydroxides of calcium and magnesium are referred to as agricultural lime.

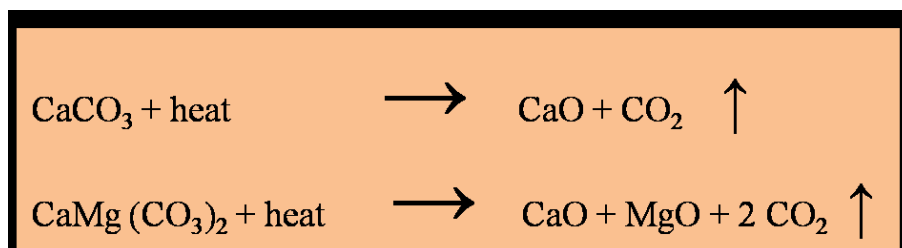
Among, the naturally occurring lime sources calcitic, dolomitic and stromatolitic limestones are important carbonates. The other liming sources are marl, oyster shells and several industrial wastes like steel mill slag, blast furnace slag, and lime sludge from

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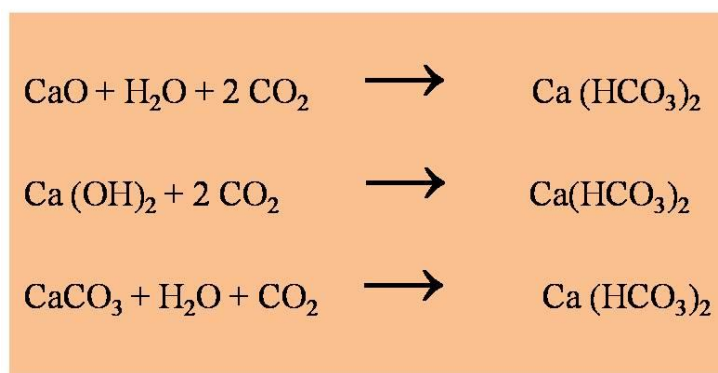
paper mills, pressmud from sugar mills, cement wastes, precipitated calcium carbonate, etc were found to be equally effective as ground limestone and are also cheaper.

Considering the efficiency of limestone as 100%, efficiencies of basic slag and dolomite were found to be 110 and 94 % respectively.

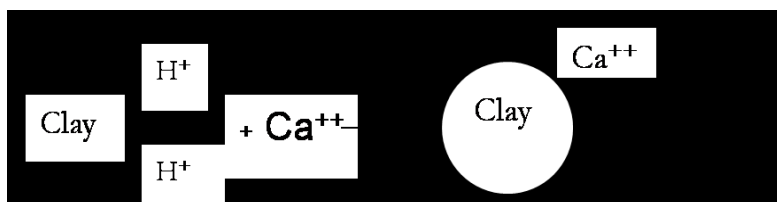
Burnt lime is the oxide of lime or quick lime. Quick lime is produced in large kilns. Its reactions in soil are much faster compared to those of carbonates.



Addition of water to burnt lime makes hydroxide or hydrated lime (slaked lime), which is more caustic than burnt lime. Lime when applied to acidic soils either in the form of oxide, hydroxide or carbonate reacts with carbon dioxide and water to form bicarbonate.



These liming materials on reaction with soil colloid, replace hydrogen and aluminium ions from the colloidal phase to soil solution.



Lime requirement

Four important factors govern the lime requirement, viz.,

- The required change in pH
- The buffer capacity of the soil to be limed
- The chemical composition of the liming materials used
- The fineness of the liming materials.

A fine textured acid soil requires much larger quantity of lime than does a sandy soil or a loamy soil with the same pH value. Calcitic or dolomitic limestone reacts slowly with soil colloids, whereas burnt lime and hydrated lime react faster and bring about changes in soil pH within a few days.

Lime requirement of an acid soil may be defined as the amount of liming material that must be added to raise the pH to some prescribed value. Shoemaker et al. (1961) buffer method is used for the determination of lime requirement of an acid soil. Lime requirement in terms of pure CaCO₃ can be observed from the following table.

pH of soil buffer suspension (Field soil sample)	lime required to bring pH down to indicated level (CaCO ₃) in tonnes per acre		
	pH 6.0	pH 6.4	pH 6.8
6.7	1.0	1.2	1.4
6.6	1.4	1.7	1.9
6.5	1.8	2.2	2.5
6.4	2.3	2.7	3.1
6.3	2.7	3.2	3.7
6.2	3.1	3.7	4.2
6.1	3.5	4.2	4.8
6.0	3.9	4.7	5.4
5.9	4.4	5.2	6.0
5.8	4.8	5.7	6.5
5.7	5.2	6.2	7.1
5.6	5.6	6.7	7.7
5.5	6.0	7.2	8.3

5.4	6.5	7.7	8.9
5.3	6.9	8.2	9.4
5.2	7.4	8.4	10.0
5.1	7.8	9.1	10.6
5.0	8.2	9.6	11.2
4.9	8.6	10.1	11.8
4.8	9.1	10.6	12.4

Benefits

The most conspicuous effect of liming was on the exchangeable acidity, which registered a decrease up to 95 %. A decrease of 70-74% in pH dependent and total acidity was recorded by liming. An average yield improvement of 30 % could be obtained.

Crop choice

Selection of crops tolerant to acidity is an effective tool to counter this soil problem and breeding of such varieties is of specific importance for attaining higher productivity, particularly in areas where liming is not an economic proposition. The crops can be grouped on the basis of their performance in different soil pH range.

Relative tolerance of crops to soil acidity

Crops	Optimum pH range
Cereals	
Maize, sorghum, wheat, barley	6.0-7.5
Milletts	5.0-6.5
Rice	4.0-6.0
Oats	5.0-7.7
Legumes	
Field beans, soybean, pea, lentil etc.	5.5-7.0
Groundnut	5.3-6.6
Other crops	
Sugarcane	6.0-7.5
Cotton	5.0-6.5
Potato	5.0-5.5
Tea	4.0-6.0

Occurrence in India

95% of soils of Assam and 30% of geographical area of Jammu and Kashmir are acidic. In West Bengal, 2.2 M ha, in Himachal Pradesh, 0.33 M ha, in Bihar, 2 Mha and all hill soils of erstwhile U.P. come under acid soils. About 80% of soils in Orissa, 88% in Kerala, 45% in Karnataka and 20% in Maharastra are acidic. The laterite zone in Tamil Nadu is covered with acid soil and about 40,000 ha are acidic in Andhra Pradesh.



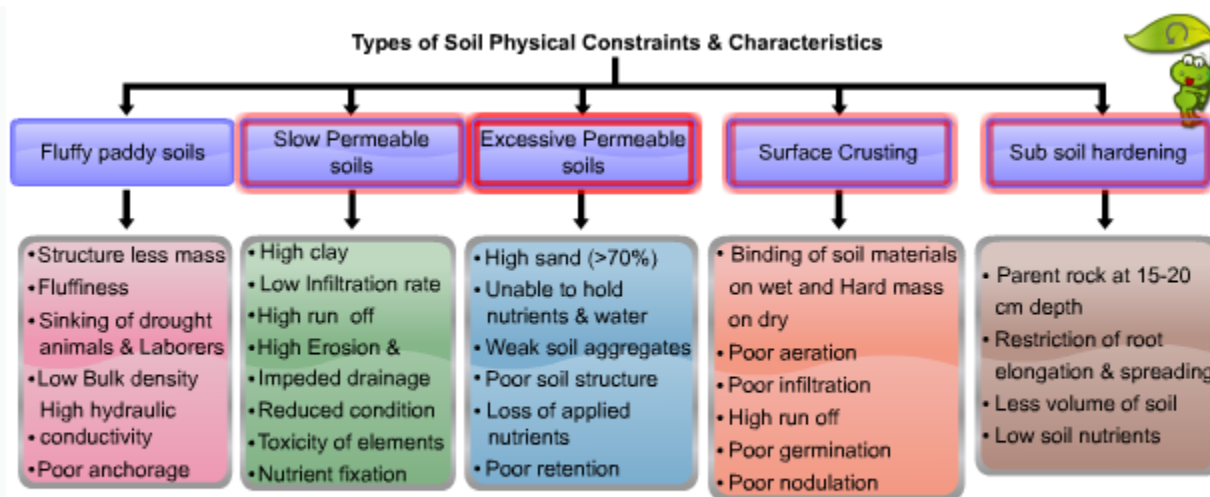
Lesson- 14

Soil physical constraints and their management

Introduction

An optimum physical environment of soils is essential for better growth of plants, consequently for better yields. Based on soils physical properties viz., infiltration, bulk density, hydraulic conductivity, porosity (capillary and non capillary, aggregates etc soil physical constraints are identified as below.

- Slow permeable soils
- Excessively permeable soils
- Subsoil hardening
- Surface crusting
- Fluffy paddy soils
- Shallow soils



Slow permeable soils

Slow permeable soils are those having infiltration rates less than 6 cm/day due to high clay content of the soil. Due to low infiltration rates, the amount of water entering the soil profile is reduced thus increasing the run-off. Further, it encourages erosion of surface soil which leads to nutrient removal in the running water. More ever, due to heavy clay content, the capillary porosity is relatively high resulting in impeded drainage and reduced soil conditions. This results in increase of some soil elements to the level of

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toxicity to the plants. It also induce nutrient fixation in the clay complex thereby nutrients become unavailable to crops, eventually causing deficiency of those fixed nutrients.

Management

1. The constraints in such soils can be managed by adopting suitable practices like
2. Provision of drainage facilities either through open or closed sub surface drains.
3. Forming contour and compartmental bunding to increase the infiltration rates of soils.
4. Application of huge quantities of river sand or red soils of coarser texture to dilute heaviness of the clayey soil.
5. Application of liberal doses of organic manures like farm yard manure, compost, green manure, composted coir pith, sewage waste, press mud etc.
6. Adopting ridges and furrows, raised beds, broad bed and furrow systems.
7. Application of soil conditioners like H-concentrate, Vermiculite, etc to reduce run-off and soil erosion.

Excessively Permeable Soils

Excessively permeable soils are those having high amount of sand exceeding 70 percent. Due to this, the soils are inert and unable to retain nutrient and water. These soils being devoid of finer particles and organic matter, the aggregates are weakly formed, the non-capillary pores dominating with very poor soil structure. Due to low retaining capacity of the soils, the fertilizer nutrients are also lost in the drainage water.

Management

The excessively permeable soils can be managed by adopting the techniques given below.

Compacting the field with 400kg stone roller (tar drum filled with 400 kg of sand or stones can

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also be used) 8-10 times at optimum moisture conditions.

Application of clay soil up to a level 100 t ha⁻¹ based on the severity of the problem and availability of clay materials.

Application of organic materials like farm yard manure, compost, press mud, sugar factory slurry, composted coir pith, sewage sludge etc.

Providing asphalt sheet, polythene sheets etc. below the soil surface to reduce the infiltration rate.

Crop rotation with green manure crops like sunhemp, sesbania, daincha, kolinchi etc.

Sub soil hardening/hard pan

The sub soil hard pan in red soils is due to illuviation of clay to the sub soil horizon coupled with cementing action of oxides of Fe, Al and calcium carbonate, which increases the bulk density to more than 1.8 Mg m⁻³. Further, the hard pan can also develop due to continuous cultivation of crops using heavy implements up to certain depth constantly. Besides, the higher exchangeable sodium content in black soil areas also results in compactness. All put together lowered the infiltration and percolation rates, nutrient movement and free air transport within the soils profile. It prevents root proliferation and limits the volume of soils available for nutrients uptake resulting in depleted, less fertile surface soil. Due to this, the contribution of sub soil fertility to crop growth is hampered.

Management

These soils are managed by adopting following practices

Ploughing the soil with chisel plough at 0.5m interval criss-cross at 0.5m depth once in 2-3 years.

Application of organics to improve the aggregation and soil structure so as to prevent

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further movement of clay to the lower layers.

Deep ploughing of the field during summer season to open up the sub soils.

Cultivating deep rooted crops like tapioca, cotton so as to encourage natural breaking of the hard pan.

Raising deep rooted semi perennial crops like mulberry, jasmine, match wood tree etc.

can also help in opening up the sub surface hard pan.

Surface crusting

Surface crusting is due to presence of colloidal oxides of iron and Aluminium in Alfisols which binds the soil particles under wet regimes. On drying it forms a hard mass on the surface. The ill effects of surface crusting are

1. Prevents germination of seeds
2. Retards/inhibits root growth.
3. Results in poor infiltration.
4. Accelerates surface run off
5. Creates poor aeration in rhizosphere
6. Affects nodules formation in leguminous crops

Management

Surface crushing can be managed as below

1. When the soil is at optimum moisture regime, ploughing is to be given.
2. Lime at 2 t ha⁻¹ may be uniformly spread and another ploughing given for blending of amendment with the surface soil.
3. Farm yard manure at 10 t ha⁻¹ or composted coir pith at 12.5 t ha⁻¹ or other organics may be applied to improve the physical properties of the soils, after preparation of land to optimum tith.
4. Scraping surface soil by tooth harrow will be useful.
5. Bold seeds may be used for sowing on the crusted soils.
6. More number of seeds/hill may be adopted for small sized seeds.
7. Sprinkling water at periodical intervals may be done whenever possible.
8. Resistant crops like cowpea can be grown

Fluffy paddy soils

The traditional method of preparing the soil for transplanting rice consists of puddling, which substantially breaks soil aggregates into a uniform structure-less mass. Under continuous flooding and submergence of soil for rice cultivation in a cropping sequence of rice-rice-rice, the soil particles are always in a state of flux and the mechanical strength is lost leading to the fluffiness of soils. Impact of fluffiness is sinking of drought animals and labourers during puddling. This has been thus, an invisible drain of finance for farmers due to high pulling

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power needed for bullocks and slow movement of labourers during puddling operations. Further fluffiness of the soil lead to very low bulk density and thereby leading to very rapid hydraulic conductivity and in turn the soil does not provide a good anchorage to the roots and the potential yield of crops is also adversely affected.

Management

Following practices are adopted to overcome this problem.

- The irrigation should be stopped 10 days before the harvest of rice crop.
- After the harvest of rice, when the soil is under semi-dry condition, compact the field by passing 400 kg stone roller or tar drum filled with 400 kg of sand for 8 times.
- The usual preparatory cultivation is carried out after compaction.

Shallow soils

The shallow soils are characterized by the presence of parent rock immediately below the soil surface at about 15-20 cm depth. This restricts the root elongation and spreading. Hence, the crops grown in these soils necessarily are shallow rooted, which can exhaust the soil within 2-3 seasons. Therefore, frequent renewal of soil fertility is a must in these soils. These soils can be managed by growing crops which can withstand the hard rocky sub soils like mango, ber, fig, country goose berry, west-Indian cherry, annona, cashew, and tamarind etc.



Lesson- 15
Genesis and characterization of water logged soils

Submerged soils

Submerged soils are soils that are saturated with water for a sufficiently long time in a year to give the soil the following distinctive gley horizons resulting from oxidation-reduction processes:

- Partially oxidized 'A' horizon
- A mottled zone
- a permanently reduced zone

Characteristics of submerged Soils

- Greater amount of soil solution
- Reduced oxygen level
- Reduced aerobic microbial activity and
- An altered chemical status of the soil

Properties of submerged Soils

Physical - O₂ depletion, CO₂ accumulation, compaction – high BD, puddling, gaseous exchange and movement of water

Chemical - Changes in reduction & transformation processes

Electro-chemical - Changes in Soil pH, Specific conductance, Eh as against normal soils

Biological - Changes in decomposition and mineralization of organic matter

Depletion of oxygen

1. Water fills the pore spaces and replaces the air
2. Oxygen diffusion in the water layer above the soil is very slow

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3. Rate of oxygen consumption in reduced soil is high
4. Surface soil profile differentiates into two distinct layers are
5. An oxidized or aerobic layer near soil surface
6. Reduced or anaerobic layer below soil surface
7. Accumulation of carbon dioxide and methane and may escape as bubbles if pressure builds up.
8. Partial pressure of CO₂ affect the solubility of the cations Ca²⁺, Mg²⁺, Fe²⁺ and Mn²⁺
9. Partial pressure of CO₂ in a soil determines its pH, Eh and solubility of cations and thereby affects the specific conductance and exchange reactions
10. Kinetics of P_{CO2} varies with soil properties
11. Decline in P_{CO2} after one to four weeks of flooding
12. Diluting effect of CH₄ produced in later stage of OM decomposition
13. Bacterial reduction of CO₂ to CH₂
14. Leaching losses
15. Removal of CO₂ as insoluble carbonates

Electrochemical changes

- Decrease in redox potential
- Increase in pH of acid soil and decrease in pH of alkaline soils
- Increase in specific conductance
- Cation exchange reactions involving Fe²⁺
- Sorption and desorption of ions

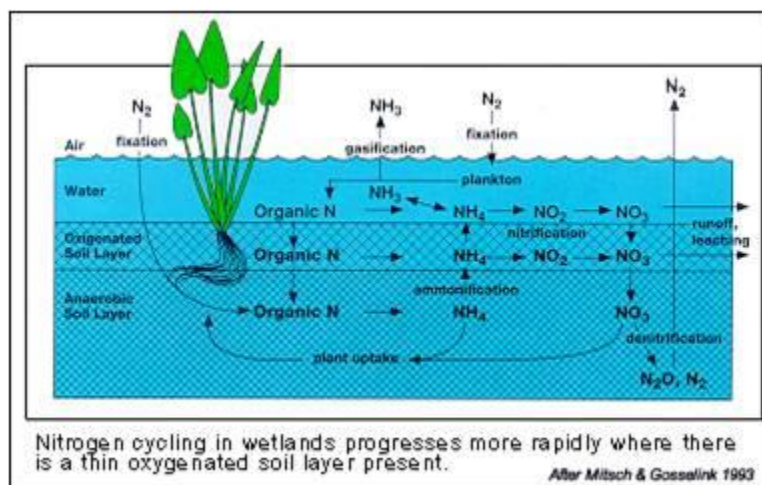
Critical Eh values of important components in submerged soils

Reduction	Eh
O ₂ to H ₂ O	+ 380 to + 320
NO ₃ to N ₂ , Mn ⁴⁺ to Mn ²⁺	+ 280 to + 220
Fe ³⁺ to Fe ²⁺	+ 180 to + 150
SO ₄ ²⁻ to S ²⁻	- 120 to - 180
CO ₂ to CH ₄	- 200 to - 280

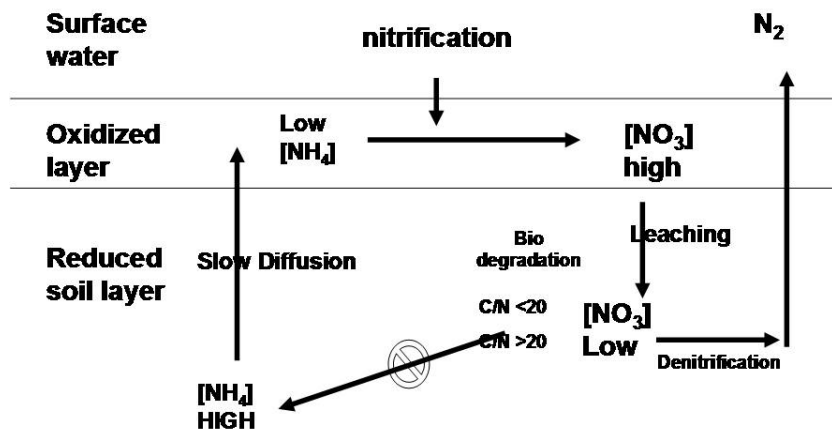
Specific conductance

- Specific conductance is related to the ionic content
- Differ with respect to the type of soil
- Alkaline soils : increase in specific conductance by Ca²⁺ and Mg²⁺
- Organic matter enhances the solubility of Ca²⁺, Mg²⁺, and Fe³⁺ and increase specific conductance.

Nitrogen Transformation in submerged soils



Simplified N transformation in submerged soils



- Mineralization of N restricted to ammonification stage
- Ammonification of organic matter also proceeds at a low rate
- Intermediate products of decomposition

28. Methane and organic acids accumulation and incomplete breakdown of carbohydrates.

29. Release of ammonia at much wider C: N ratio (Low N requirement of anaerobic)

Phosphorus

- The mobility of P is higher (diffusion process gets increased).
- The P mobility is restricted to the top 30 cm layer of the soil even in submerged conditions.
- The P fixation is more (fixation/ chemisorptions of P on colloids will be more).
- At the same time, when the colloidal fractions of P get mineralized, it results in more availability.
- The solubility of P compounds gets increased due to the presence of CO₂ and decrease in Eh.
- Hydrolysis of P compounds and its solubility of will be more leading to the higher solution P (available P).
- The mineralization of organic P will be higher.

Potassium

- Increase in K availability due to Fe²⁺
- Release from micas
- However the availability of applied K decrease due to the formation of sparingly soluble Fe-K complex

Sulphur

SO₄²⁻ reduced to H₂S and then to FeS. It has three implications. They are

- S supply may become insufficient
- Zn & Cu may be immobilized and
- H₂S toxicity may arise in soils low in Fe

Manganese

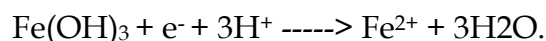
- In submerged soils,
- $MnO_2 + 4 H^+ + 2e^- \text{ (reduction) } Mn^{2+} + 2H_2O$

(Insoluble) (Water soluble, available to plant)

- The above reaction occurs almost coincident with the disappearance of molecular oxygen and NO₃-N resulting in the formation of manganous compounds.
- Water soluble and exchangeable ion increases on submergence and ensures a better supply of Mn in flooded soils to rice.

Iron

- In waterlogged conditions, Fe³⁺ is reduced to Fe²⁺ with concomitant increase in Fe solubility by anaerobic bacteria, which uses iron oxides as electron acceptors in respiration. It produces toxic effect in rice plants called 'bronzing disease'.
- Under anaerobic conditions, owing to the reducing process, hydrous iron oxides give rise to Fe²⁺ according to the following equation.



Zinc

- Zn deficiency in flooded soils thought to be related to high pH or the presence of CaCO₃. However, Zn deficiency also occurs in acid soils.
- When soils are submerged, the concentration of many nutrients increases, but not Zn.
- In acid soils, Zn deficiency may be attributed to the increases in pH under reducing conditions and subsequent precipitation of franklinite or sphalerite.
- Decreasing pH in submerged, calcareous soils would usually increase Zn solubility.
- However, higher soil pH - poorer the aeration and greater the Zn deficiency.



Lesson- 16

Quality of irrigation water-Criteria and Parameters used for Judgment

INTRODUCTION

It is necessary to ascertain the quality of irrigation water so as to gauge the possible effects of this water on the soil. The irrigation water often results in water logging, salinity and alkalinity problems. It is therefore very important to know its quality. Following are the basic criteria or characteristics on which irrigation water quality is judged.

1. Presence of total soluble salts in irrigation water.
2. Proportion of carbonates and bicarbonates in relation to calcium and magnesium in irrigation water.
3. Proportion of sodium in relation to other cations in irrigation water.
4. Concentration of specific ions in irrigation water.

Several parameters are employed to judge the quality of irrigation waters No parameter in complete in judging the quality of irrigation water. Further the quality of water should be judged by considering the crop and soil factors. Any judgment without considering the above factors may not be useful. Researchers devised many parameters by following above said criteria. Some of the commonly adopted parameters used to judge the quality of irrigation water are

- Electrical conductivity of irrigation water
- Potential salinity
- Puri's salt index
- Sodium adsorption ratio
- Soluble sodium percentage
- Residual sodium carbonate
- Permeability index
- Boron concentration in water

Parameters used to judge the quality of irrigation waters

a. Electrical conductivity (EC)

It is a measure of total soluble salts in water. Since there exist proportionality between concentration of salts in water and electrical conductance the EC is commonly employed as one of the important parameter to judge water quality with respect to salinity. There are many classification available based on EC namely USDA, USSR and Tamil Nadu STL etc. But most widely used one is USDA classification.

b. Potential salinity (PS)

This considers the concentrations of chloride and sulphate in irrigation water. The potential salinity of irrigation water can be derived using the formula

$$PS = \frac{1}{2} SO_4^{2-} + Cl^-$$

c. Puri's salt index (PSI)

Puri's salt index accounts relationship between concentrations of Na and Ca ions in a given irrigation water. PSI can be arrived by applying the concentration values of water in the following formula

$$PSI = (Total Na^+ - 24.5) - (Total Ca^{2+} - Ca as CaCO_3) \times 4.85$$

d. Sodium Adsorption Ratio (SAR)

This explains the relationship between concentrations of sodium and calcium & magnesium of irrigation water. SAR of given water can be worked out by using the formula

$$Sodium\ Adsorption\ Ratio\ (SAR) = \frac{Na}{\sqrt{Ca + Mg^2}}$$

e. Soluble sodium percentage (SSP)

The proportion of sodium with that of total cations in a given irrigation water is considered to judge the quality under soluble sodium percentage. in relation to total cations in water

$$SSP = \frac{Na}{Total\ Cations\ (Ca + Mg + K + Na)} \times 100$$

f. Residual sodium carbonate (RSC)

In this parameter the proportion of carbonates & bicarbonates in relation calcium & magnesium in irrigation water is considered. Applying concentration values of carbonate, bicarbonate, calcium and magnesium in the following formula the RSC of water is arrived

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca + Mg)$$

g. Permeability Index (PI)

This parameter explains ratio between Na & HCO₃ and cations like calcium, magnesium and sodium in irrigation water.

$$Permeability\ Index\ (PI) = \frac{Na + HCO_3 \times 100}{Ca + Mg + Na}$$

h. Boron concentration

The specific ion effect is taken here to judge the quality of irrigation water. Any ion for that matter exceeds certain limit considered poor quality and may not be suitable for irrigation. Boron being highly soluble in water the concentration of boron is often found to be high in many locations. Hence B concentration in water is commonly considered as one of the parameter to judge the quality of irrigation water.

A part from boron, excess concentrations of ions like carbonate, bicarbonate, chloride, sulphate, nitrate, fluorine and heavy metals including nickel, lead, cadmium *etc.*, are also injurious to

Soil and Plant Analysis

growing plants in specific locations. Boron is excessively available in some locations which makes the water quality poor. Further, the critical limits are varying with ions, soil type and crops.



Lesson- 17

Classification of Irrigation Water and Management of Poor Quality Water

Introduction

- In classification of irrigation water, it is assumed that the water will be used for average conditions with respect to soil texture, infiltration rate, drainage, quantity of water used, climate and salt tolerance of the crop.
- Large deviations from the average for one or more of these variables may make it unsafe to use what, under average conditions, would be a good water; or may make it safe to use what, under average conditions, would be a water of doubtful quality.
- The relationship to average conditions must be kept in mind in connection with the use of any general method for the classification of irrigation water.
- However the quality of irrigation water is evaluated, mainly by the quantity of dissolved salts, proportion of anions, monovalent and divalent cations, sodium adsorption ratio, residual sodium carbonate, potential salinity, specific ion toxicity, proportion of magnesium, calcium in water etc.

1. Salinity based on E.C – USDA system:

- < 250 μ .mhos/cm : Low saline : Good
- 250 – 750 μ .mhos/cm : Medium saline : Fair
- 750 – 2250 μ .mhos/cm : High saline : Poor
- > 2250 μ .mhos/cm : Very high saline : Very poor

2. Potential Salinity (PS)

<i>PS of water</i>	<i>Soil type suitable</i>
1 and 3 me/L	fine, medium and coarse textured soils
3 and 15 me/L	safely used in medium and coarse textured soils
15 and 20 me/L	safely used only in coarse textured soils

3. Puri's Salt Index (PSI)

<i>PSI of water</i>	<i>suitability</i>
negative	good quality and suitable for irrigation
positive	poor quality water and unsuitable for irrigation

4. Sodium Adsorption Ratio (SAR)

<i>SAR of water</i>	<i>suitability</i>
<10	Low sodic water
10.1 - 18.0	Medium sodic water
18.1 - 26.0	High sodic water
> 26	Very high sodic water

5. Soluble Sodium Percentage (SSP)

<i>SSP of water</i>	<i>suitability</i>
< 60 per cent	good quality and suitable for irrigation
> 60 per cent	poor quality water and unsuitable for irrigation

6. Residual Sodium Carbonate (RSC)

<i>RSC of water</i>	<i>suitability</i>
<1.25 me/L	good quality water
1.25 - 2.5 me/L	fair quality water
>2.5 me/L	poor quality water and unsuitable for irrigation

7. Permeability Index (PI)

$$PI = \frac{Na + HCO_3}{Ca + Mg + Na} \times 100$$

Ca + Mg + Na

- PI <60 per cent - good quality water and suitable for irrigation
- PI >60 per cent - poor quality water and unsuitable for irrigation

8. Boron Concentration

- < 0.5 ppm - Low
- 0.5 - 1.0 ppm - Medium
- 1.0 - 2.0 ppm - High
- 2.0 - 4.0 ppm - Very high
- > 4.0 ppm - Excessive

9. Fluorine Concentration

- < 1 ppm - Good
- > 1 ppm - Problematic

10. Combined Evaluation on the Basis of EC & SAR

United States Salinity Laboratory (Richards, 1954) published a semi logarithmic diagram, which rates water with respect to EC and SAR. Four classes of each salinity and SAR were divided as shown below in the table.

Salinity Hazard	Class	EC m.mhos/cm	Sodium Hazard	Class	SAR
Low	C1	< 0.250	Low	S1	< 10
Medium	C2	0.250 - 0.750	Medium	S2	10 - 18
High	C3	0.750 - 2.250	High	S3	18 - 26
Very high	C4	>2.250	Very high	S4	>26

Management of poor quality irrigation waters

a. Saline water

1. Crop management

Growing crops that are tolerant high level soil salinity e.g.: Cotton, Ragi, Barley, sugar beat, Beet root, curry leaf, Bermuda grass, saline grass, spinach etc.

Crops that are tolerant to soil salinity at medium level are paddy, wheat, onion, maize, sunflower, castor, grape, pomegranate, tomato, cabbage and potato.

Crops that are tolerant to low level of soil salinity are garden beans, Reddish, lime etc. Black gram and green gram are sensitive to soil salinity.

Crops are to be chosen based on the soil salinity level.

Relative tolerance of crops to salinity

Plant species	Threshold salinity (dS m-1)
Field crops	
Cotton	7.7
Sugar beet	7.0
Sorghum	6.8
Wheat	6.0
Soybean	5.0

Groundnut	3.2
Rice	3.0
Maize	1.7
Sugarcane	1.7
Vegetables	
Tomato	2.5
Cabbage	1.8
Potato	1.7
Onion	1.2
Carrot	1.0
Fruits	
Citrus	1.7

2. Soil / cultural management

Growing crops in raised beds will reduce accumulation of salt around root zone. Planting seedlings / sowing seeds on sloppy ridges decreases accumulation of salts around root zone. Mulching soil prevents evaporation which reduces accumulation of salts due to capillary rise of water at surface of soils. Providing drainage in water logged areas also helps to reduce salt accumulation.

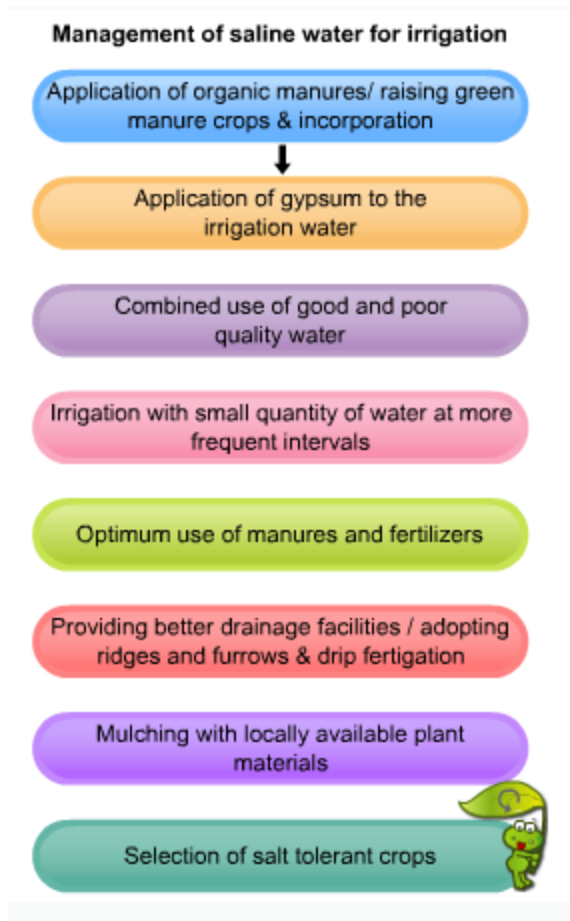
3. Fertilizer Management

Addition of extra dose of nitrogen to the tune of 20 - 25% of recommended level will compensate the low availability of N in these soils. Addition of organic manures like, FYM, compost, etc helps in reducing the ill effect of salinity due to release of organic acids produced during decomposition. Green manuring (sun hemp, Daincha) and / or green leaf manuring also counteracts the effects of salinity.

4. Irrigation management

Proportional mixing of good quality (if available) water with saline water and then using for irrigation reduces effect of salinity. Alternate furrow irrigation favors growth of plant than flooding. Drip and sparkler irrigation systems aim to reduce the use of water which is favorable for growth of plant since salt accumulation also reduced with low usage of water.

All the above four management practices suitably integrated to reduce the soil salinity, which is favorable for better growth of plants and ultimately for better yields. Management of saline soils becomes essentials and unavoidable particularly in areas where both soil as well as irrigation water are saline in nature.



b. Sodic water

Calculated quantities of gypsum added based on RSC along with irrigation water to reduce the ill effect of sodicity on soil and plants. The techniques employed for soil sodicity can also be followed.

Exercise.1

Collection and preparation of soil samples for analysis

Soil is analyzed to know the nature of soil, to classify and advocate to farmers about the peculiarities of the soils and how much of fertilizers should be applied for better crop production.

A complete soil, of course, cannot be moved into a laboratory. The value of the laboratory work depends upon *care in sampling*. Each soil sample needs to be a fair representative of the specific area or horizon worth sampling.

If the sample is to be a representative of an area, it is necessary to take large numbers of samples spread over the area, pool them and sub-sample it so as to get a sample of desired size. For soil survey work, samples are collected from a profile typical of the soil of the surrounding area.

Materials required

(i) Spade (ii) Khurpi (iii) Auger (screw or posthole type) (iv) Core sampler (v) Soil testing tube (for wet soil) (vi) Sampling bags and (vii) Plastic basin or Bucket.

Collection of soil samples from the field

Normally each field may be treated as a sampling unit. But two or more fields, which are similar in appearance, production and past-management practices, may be grouped together into a single sampling unit. Samples should be collected separately from areas, which differ in soil colour or past-management practices such as liming, fertilization, cropping pattern etc. During collection of soil, avoid dead furrows, old manure or lime piles, wet spots, areas near trees, manure pits, compost pits and irrigation channels. The sampling should be done in a zig zag pattern across the field to get homogeneity. A wise collecting agent is one who collects samples in the presence of the owner or cultivator of the land who is the best judge in deciding which area of his farm should be sampled separately.

Scrap away the surface litter and insert the sampling auger to plough depth (15 cm). Take at least 15 samples randomly distributed over each area and place them in a clean bucket. If a sampling auger is not available make a 'V' shaped cut to a depth of 15

cm using a spade and remove 1.0 to 1.5 cm thick slice of soil from top to bottom of the exposed face of the 'V' shaped cut and place in a clean bucket or basin.

Thoroughly mix soil samples taken from 15 or more spots of each area. Remove foreign bodies such as plant roots, stubbles, pebbles, stones or gravels. By quartering, discard all but $\frac{1}{2}$ to 1 kg soil. Quartering is done by dividing the thoroughly mixed soil into four equal parts and discarding two opposite quarters. Remix the remaining two quarters and again divide into four equal parts and reject the opposite two. Repeat this procedure until about $\frac{1}{2}$ to 1 kg of soil is left. Instead of quartering, compartmentalization method can also be followed. For this, spread the soil on a clean hard surface and mark lines from both the sides and create number of compartments. Take a little quantity of soil from each compartment and put into a clean container. Repeat the process of collection until the required quantity is collected. Store the soil in a clean cloth bag or container with proper labeling for further analysis.

Note: i) Sampling should be done after the harvest of the crop.

ii) In case sampling is necessary during crop growth, samples should be collected between the lines of growing plants.

iii) Avoid storing soil samples in fertilizer bags.

Collection of soil samples from a profile

After the profile has been exposed, clean one face of the pit carefully with a spade and note the succession and depth of each horizon. Prick the surface with a knife or edge of the spade to show up structure, colour and compactness. Describe the profile as per the standard terminologies. Use the Munsell colour chart for noting the colour and find out the texture by feel method.

Collect samples from each horizon by holding a large basin at the bottom limit of the horizon while the soil above is loosened by a khurpi. The sample is mixed and transferred to a bag after labeling.

Preparation of soil sample for analysis

The soil sample received at the laboratory is air dried in shade and spread on a sheet of paper after breaking large lumps if present, with a wooden mallet. It is further

ground by pounding with a wooden mallet in such a way that the aggregate particles are broken down to ultimate soil particles. The soil thus prepared is sieved through a sieve with round holes, 2 mm in diameter. The material on the sieve is again ground and sieved till all aggregate particles are fine enough to pass through and only stones and organic residues remain on the sieve. Mix well the 'fine soil' got by sieving and store in a suitable bottle or container with one label on the outside and another inside the container.

For determination of organic carbon, powder and sieve the soil through 0.5 mm sieve. For the soil samples meant for micronutrient analysis, iron, brass, copper and zinc containers must be avoided for collection and storage of soil samples.

Sub-sampling for analysis

The soil in the bottle is emptied on a clean thick sheet of paper and evenly spread with a sampling knife. It is heaped into a cone by raising the four ends of the paper. It is again mixed well and evenly spread on the paper as before. The process is repeated 3 or 4 times to ensure uniformity and then finally spread evenly on the paper again. Now it is divided into four equal quarters and small quantity of soil is taken from various points in each quarter to get a representative sample for analysis.

Exercise.2**Estimation of moisture content in soil and plant samples
(Gravimetric method)****In soil samples****Principle**

Soil moisture content is determined by drying a known quantity of soil sample in an electric oven at 105°C to 110°C and finding out the loss in weight.

Materials required

1. Moisture bottle / aluminum box
2. Chemical balance / top pan balance
3. Desiccator

Procedure

Place a clean and empty moisture bottle or aluminium container with lid separately in an electric oven at 105°C for 15 minutes. Replace the stopper or lid; remove the moisture bottle or aluminum box from oven. Cool in a desiccator, weigh accurately and record the weight. Fill the moisture bottle or aluminium container to about two third of its capacity with soil sample. Close with stopper / lid and weigh quickly. Remove the stopper / lid and keep it in the oven at 105°C for about 8 hours. After the expiry of time, remove the moisture bottle / aluminium container, cool it in a desiccator and weigh quickly. Calculate the loss in weight and express the moisture content on oven dry basis.

Observations and Calculations

Weight of the empty moisture bottle	=	a g
Weight of the moisture bottle + moist soil sample before drying	} =	b g
Weight of the moisture bottle + soil sample after drying in the oven	} =	c g
Weight of moisture in the soil	=	(b - c) g
Percentage of moisture in the soil sample on oven dry basis	} =	$\frac{(b - c)}{(c - a)} \times 100$

In plant samples

Principle

Moisture content in plant sample is determined by drying a known quantity of sample in an electric oven at 60°C to 70°C and finding out the loss in weight.

Materials Required

1. Moisture bottle (weighing bottle), 2. Chemical balance, 3. Desiccator

Procedure

Place a weighing bottle with its stopper separately in an electric oven at 100 – 105°C for about 15 minutes. Replace the stopper, remove the moisture bottle from oven and place it in a desiccator. Cool it and record the weight. Transfer about 5 g of the given sample to the bottle. Stopper it and weigh quickly. Remove the stopper and keep it in a hot air oven at 60-70°C for 6 hrs. At the expiry of time, replace the stopper and remove the moisture bottle from the oven. Cool in the desiccator and weigh quickly. Calculate the loss in weight and express it in percentage.

Observations and Calculations

Weight of the empty weighing bottle alone	= a g
Weight of the weighing bottle + plant sample before drying	= b g
Weight of the weighing bottle + plant sample after drying in the oven	= c g
Weight of moisture in the plant sample	= (b - c) g
	(b - c)
Percentage of moisture in the plant sample =	= ----- x 100
	(c - a)

Exercise.3**Determination of hydraulic conductivity in soil****Principle**

The rate of flow of a liquid through a porous medium depends on the size, distribution of the pores and temperature of the liquid, which is indexed as hydraulic conductivity. In saturated soil it is directly related to permeability.

Materials required

Core sample along with ring / hydraulic head with tubes / stop clock / beaker / core sample stand.

Procedure

Preparation of soil sample: Keep the core sample in water for saturation for 24 hrs. Remove the guard rings carefully without disturbing the pores using a knife.

Water supply: Attach the water supply unit to the constant water head, which is attached above the core sample and allow the water to pass through the soil column.

Measurement: Collect the water percolating through the soil column at periodical intervals till the volume of water collected becomes constant. Record the length of soil column (L) and hydraulic head (ΔH).

Calculation

The rate of flow of a liquid in a saturated soil column follows Darcy's law;

$$K = \frac{QL}{\Delta H \times AT}$$

Where,

K = Rate of flow of water (cm / hr)

Q = Quantity of water collected (ml)

L = Length of soil column (cm)

ΔH = Hydraulic head (cm)

A = Cross sectional area of the cylinder (cm²)

T = Time interval (minutes)

Result

The hydraulic conductivity of the given soil sample = cm / h

Exercise.4

Determination of water holding capacity of soil

(Pressure plate apparatus method)

Principle

The amount of water retained in the soil under different pressure depends upon the soil pore size. When pressure is applied to a saturated soil some amount of water will be drained away until the pores have a diameter corresponding to the applied pressure. The moisture content at this equilibrium is an important characteristic of the soil. When a saturated soil is subjected to 1/3 and 15 bar pressure the moisture retained at equilibrium point under these two pressures respectively is considered to be field capacity and wilting point moisture.

Equipments

Pressure plate apparatus with air compressor, pressure line, pressure chamber and porous ceramic plate.

Procedure

Arrange the rubber rings in the ceramic porous plate (separate ceramic plates are available for different pressures). Take about 25 g of soil passed through 2 mm sieve and put it into the rubber ring and level the top to the rim of the ring. Keep the porous plate with the rubber rings containing soil in a tray having water and saturate over night (distilled water is preferable for saturation). Keep the porous plate with the soil in the extractor / pressure chamber and connect to the outlet tube of the extractor. Close the extractor with the lid and see that the lid is airtight. Connect the air compressor to power supply and start the motor to build up pressure. When adequate pressure is built up, open the pressure line and regulate the pressure by using the pressure gauge to the desired level (i.e. 1/3 bar for field capacity and 15 bar for wilting point moisture). Allow the soil to attain equilibrium at the desired pressure. Stoppage of water dipping from the out let tube of the extractor indicates the attainment of equilibrium. At this stage close the pressure line and air compressor, release the excess pressure and remove the pressure plate after opening the extractor. Transfer the soil in the rubber ring to an aluminium tin whose

weight has already been determined and dry it in an air oven and determine the moisture content gravimetrically.

Calculation

Moisture content at 1/3 bar (field capacity)

Weight of the moist soil + aluminium tin = A g

Weight of oven dry soil + tin = B g

Weight of empty tin = C g

Water lost due to oven drying

$$\text{Moisture retained} = \frac{\text{-----}}{\text{Weight of oven dry soil}} \times 100$$

$$= \frac{(A - B) - (B - C)}{(B - C)} \times 100$$

*** Similarly determine the moisture content at 15 bars.**

Difference in moisture content between 1/3 and 15 bars is available moisture.

Result

Exercise.5**Determination of soil pH and EC****pH**

The pH is defined as the negative logarithm of hydrogen ion concentration or simply the log of the reciprocal of the hydrogen ion concentration (Sorenson, 1906).

$$\text{pH} = -\log [\text{H}^+] = \log 1/(\text{H}^+)$$

Principle

A glass electrode in contact with H ions of the solution acquires an electric potential which depends on the concentration of H ions. This is measured potentiometrically against some reference electrode, which is usually a calomel electrode. The potential difference between glass electrode and calomel electrode is expressed in pH units.

Two electrodes are used in the determination of pH. One is reference electrode, which provides a standard voltage. The reference electrode is usually a saturated calomel electrode which has two layers (1) saturated solution of KCl and (2) mixture of solid HgCl_2 (Calomel) and Hg. The outer tube is usually 5-15 cm long, 0.5-1 cm in diameter. The mixture of solid $\text{HgCl}_2 + \text{Hg}$ paste is contained in an inner tube that is connected to the saturated KCl solution in the outer tube by means of small opening. The resistance of this type of electrode is 2000-3000 ohms.

The outer electrode is glass electrode that consists of a tube enclosing a lead wire made of Ag coated with AgCl. This wire is again enclosed in wax insulation. The bottom of the tube is attached with a glass bulb made of a special kind of glass which is sensitive to H ions. The thickness of the glass membrane varies from 0.03 to 0.1 mm and has a resistance of 50 to 500 mega ohms.

When these two electrodes are dipped in solution, the saturated solution of KCl comes out of reference electrode through the small holes and forms an invisible ionic bridge between electrodes through which current passes. The H ions are absorbed by glass electrode and an electric potential develops between electrodes depending on the

amount of H ions present in the solution. This potential difference is measured in terms of pH by suitable galvanometer.

Materials required

- | | |
|--------------|--|
| 1) pH meter | 2) 100 ml beakers |
| 3) Glass rod | 4) Buffer solution (pH 4.0, 7.0 and 9.2) |

Procedure

Caliberation of pH meter

- Switch on the instrument and allow it to warm for 10 minutes
- Keep the pH selector switch on zero position
- Set the temperature compensation control to the solution temperature
- Adjust the zero adjustment knob so that the pointer in the meter reads exactly zero, when the electrodes are immersed in distilled water.
- Lift the electrodes from distilled water and wipe it dry using filter paper and dip them in standard buffer solution of known pH (4.0, 7.0 and 9.2)
- Change the function switch to particular pH ranges (0-7 or 7-14) and adjust the standardization knob till the pointer reads the correct pH value of the buffer solutions. Do not disturb the zero knob adjustment.

pH measurement

- Weigh 20 g of air dried soil passed through 2 mm sieve and transfer to a clean 100 ml beaker
- Add 50 ml of distilled water (1: 2.5 ratio)
- Using glass rod, stir the content intermittently and allow it to stand for half an hour.
- Wash the electrodes carefully with a jet of distilled water and wipe it dry with a piece of filter paper.
- Stir the soil suspension again just before taking the reading.

- Immerse the electrodes into the beaker containing soil water suspension and change the function switch to the particular pH range.
- Record the meter reading.

Result

The pH of the given soil sample is = -----

Electrical conductivity (EC)

The electrical conductivity (EC) measurement gives the total amount of soluble salts present in the soil and is expressed as millimhos/cm or dSm^{-1}

Principle

As the amount of the soluble salts in a solution increases the electrical conductivity also increases. This electrical conductivity is measured in terms of the resistance offered to the flow of current using a conductivity bridge.

It is known that solutions offer some resistance to the passage of electric current through them, depending upon the concentration of salts present. Hence EC is measured in terms of electrical resistance between parallel electrodes immersed in the soil suspension of water. In such a system, the solution between the electrodes becomes the electrical conductor to which the physical laws relating to resistance are applicable. The electrical resistance “R” is directly proportional to the distance “L” between the electrodes and inversely proportional to the cross sectional area “A” of the conductor.

Hence $R = L / A$ or $R = r \times L / A$

Where r = proportionality constant known as electrical resistivity

If $L = 1 \text{ cm}$ and $A = 1 \text{ cm}^2$ then $R = r$.

Where ‘r’ is called specific resistivity. Hence specific resistance is the resistance of a conductor of 1 cm in length and 1 cm^2 in area.

Higher the salt content, higher the passage of current and lesser the resistance to the flow of the current. Hence the reciprocal of specific resistivity is called as specific

conductivity. Therefore specific conductivity is defined as the conductivity of a solution enclosed in a cell whose electrodes are exactly 1 cm and possess a surface area of 1 cm². The resistance is expressed as ohms/cm and the conductivity is expressed in reciprocal ohms or mhos per cm. It is not possible to make a conductivity bridge having electrodes 1sq.cm in area and place exactly 1 cm apart. Hence, the factor called the cell constant is determined for the given cell. Modern conductivity meters are calibrated to read directly the electrical conductance with given cell.

Materials required

- 1) Conductivity bridge
- 2) 100 ml beaker
- 3) Glass rod
- 4) 0.01 N KCl solution
- 5). Saturated CaSO₄ solution

Procedure

Switch on the conductivity bridge and wait for 10 minutes. Check the instrument, with saturated CaSO₄ solution and 0.01 N KCl solutions. The EC of saturated CaSO₄ and 0.01 N KCl solutions should be **2.2 dSm⁻¹** and **1.41 dSm⁻¹** respectively.

Use the same soil water suspension used for measuring pH for the determination of EC. Stir the contents and allow the soil to settle for 15 minutes. Wash the electrodes carefully and immerse them into soil solution. Adjust the temperature correction. Adjust the meter knob until the magic eye of the null indicator is at the widest in width. The readings on the scale at this position indicate the electrical conductivity. Multiply this by the cell constant (noted on the cell itself) to get specific conductivity.

Result

The electrical conductivity of the given soil sample is = -----

Exercise.6 & 7

Estimation of Cation Exchange Capacity and ESP

Cation exchange capacity

Principle

The cation exchange capacity of the soil involves measuring the total quantity of negative charges per unit weight of the soil. It is determined by leaching a known amount of soil using neutral salt solution (usually neutral normal ammonium acetate) and then estimating the quantity of cation (NH_4) adsorbed in the soil by distillation.

Reagents

1. Neutral Normal ammonium acetate
2. 60% alcohol
3. Solid ammonium chloride
4. 0.1 N H_2SO_4
5. 0.1N KOH
6. Methyl red indicator
7. Red litmus paper
8. MgO

Procedure

- Take 10 g of air-dry soil in a 250 ml beaker and add 50 ml of neutral normal ammonium acetate solution stir well and keep it overnight covering with a watch glass.
- Transfer the soil to the filter paper; leach it with 25 or 30 ml portions of ammonium acetate solution 6-8 times and collect the filtrate in a beaker (*Transfer the filtrate to a 250 ml of volumetric flask, make up the volume to the mark and preserve it for the estimation of individual exchangeable cations*).

- Add a pinch of solid ammonium chloride and leach with 60% alcohol. Continue washing of the residue till the filtrate runs free of chloride.
- Remove the filter paper with the soil cautiously and place it in a nitrogen distillation flask. Add distilled water till the flask is half full (about 400 ml).
- Pipette out 25 ml of 0.1 N H_2SO_4 into a 500 ml ice tumbler and add 1 or 2 drops of methyl red indicator.
- Place the ice tumbler below the delivery end and ensure that the delivery end touches the surface of the 0.1N H_2SO_4 .
- Add 1g of freshly ignited MgO to the flask containing the soil.
- Stopper the flask immediately and start distillation. Test for free of ammonia using red litmus by keeping it at the delivery end.
- If the red litmus turns to blue, continue the distillation. If it remains as red, it shows the completion of ammonia evolution.
- Wash the end of the delivery tube with distilled water into the same ice tumbler when the distillate runs free of ammonia.
- Remove the ice tumbler and titrate the excess acid against 0.1N KOH .
- The end point is change of colour from red to straw yellow.

Observations

N/10 H_2SO_4 vs N/10 KOH

S.No.	Volume of N/10 H_2SO_4 taken (ml)	Burette Readings (ml)		Volume of N/10 KOH used (ml)	Indicator	End point
		Initial	Final			

Calculation

Weight of soil taken	= 10 g
Volume of 0.1 N H ₂ SO ₄ taken	= V ml
Volume of 0.1 N KOH consumed	= V ₁ ml
Actual volume of 0.1 N H ₂ SO ₄ consumed	= (V – V ₁) ml
1 ml of 0.1N H ₂ SO ₄	= 0.1 m. e. of any ion
Cation exchange capacity	= (V-V ₁) x 0.1 x 100/10 m. e. /100 g soil

Result

The cation exchange capacity of the given soil sample is = ----- m.e. / 100g soil

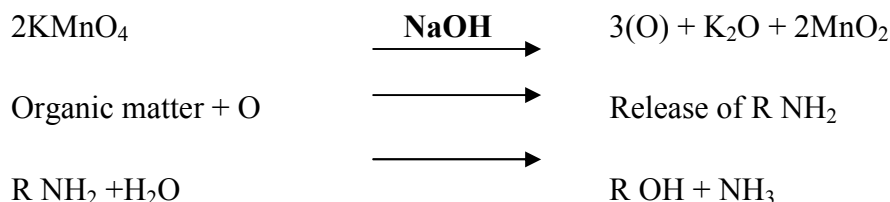
Exchangeable sodium percentage (ESP)

In CEC filtrate estimate the exchangeable calcium and magnesium by versenate titration and sodium by flame photometer (Refer analysis of Ca, Mg and Na in irrigation water). Express the results of Ca, Mg and Na in m.e / 100g soil. The ESP of the soil can be arrived by the formula

$$\text{Exchangeable sodium percentage} = \frac{\text{Exchangeable Na}}{\text{CEC}} \times 100$$

Exercise.8**Estimation of Available Nitrogen in Soil****(Alkaline permanganate method)****Principle**

A known weight of soil is mixed with excess of alkaline permanganate and distilled. The nascent oxygen liberated by KMnO_4 in the presence of NaOH oxidizes organic matter present in soil and thus ammonia is released. The released ammonia is absorbed in boric acid containing double indicator and converted to ammonium borate, which is titrated against standard H_2SO_4 .

Reactions**Reagents required**

- i). 0.32 % KMnO_4 solution (3.2 g of KMnO_4 in 1 litre distilled water)
- ii). 2.5% NaOH solution (25g of NaOH in 1 litre distilled water)
- iii). 2% boric acid (20 g of boric acid dissolved in 1 litre of distilled water)
- iv). N/50 H_2SO_4 .
- v). Double indicator -Bromocresol green (0.5 g) and methyl red (0.1g) dissolved in 100 ml of ethyl alcohol

Apparatus Required

- i). Distillation assembly
- ii). Burette
- iii). Beaker 100 ml.

Procedure

- ❖ Weigh and transfer 20 g of soil into a distillation flask.
- ❖ Add 30 ml of distilled water just to moist the soil and 1 ml of liquid paraffin or 1 g paraffin wax (to avoid frothing). Do not add excess water.
- ❖ Add few pieces of glass beads /porcelain pieces (to avoid bumping). Add 100 ml of freshly prepared 0.32 % KMnO_4 .
- ❖ Keep a 100 ml beaker containing approximately 20 ml of 2 % boric acid with double indicator below the delivery end of the condenser in the distillation set.
- ❖ See that the delivery end should touch the acid. Add 100 ml of 2.5 % NaOH to the soil in the distillation flask
- ❖ Distill the contents at a steady rate and collect the liberated ammonia in boric acid.
- ❖ Continue the distillation until 30 ml of distillate collected or exactly for half an hour.
- ❖ Titrate the ammonia collected in boric acid with N/50 H_2SO_4 .

Observations**Ammonium borate vs. N/50 H_2SO_4**

S. No.	Volume of Boric acid taken (ml)	Burette Reading (ml)		Volume of N/50 H_2SO_4 used (ml)	Indicator	End point
		Initial	Final			

Calculation

Weight of the soil taken	=	20 g
Volume of N/50 H ₂ SO ₄ consumed	=	X ml (titre value)
1 ml of N/50 H ₂ SO ₄	=	0.00028 g N
X ml of N/50 H ₂ SO ₄	=	0.00028 x X g N
This is present in 20 g of soil		
		0.00028 (X) 2.24 x 10 ⁶
Therefore N present in kg/ha	=	$\frac{\quad\quad\quad}{20}$

Result

Exercise.9

Estimation of Available Phosphorus in Soil

(Bray No. 1 method for acid soils)

Principle

The combination of HCl and NH_4F extracts soluble forms of P. The fluoride ion complexes Al^{3+} , Fe^{3+} and thus allowing P to come into the solution. The amount of P extracted is determined colorimetrically.

Reagents required

Bray no.1 extractant (0.03 N NH_4F and 0.025 N HCl)

- (1) 37 g of NH_4F is dissolved in one litre of distilled water (this is 1N NH_4F)
- (2) 20.2 ml of conc. HCl is diluted to 500 ml with distilled water (this is 0.5 N HCl);
- (3) 15 ml of 1N NH_4F and 25 ml of 0.5 N HCl are mixed and the volume is made up to 500 ml with distilled water. This gives a solution of 0.03 N NH_4F and 0.025 N HCl.

Reagent A

- Dissolve 12 g of ammonium molybdate in 250 ml of distilled water,
- Dissolve 0.291 g of antimony potassium tartrate in 100 ml water.
- Prepare 1000 ml of 5N H_2SO_4 (138 ml of Conc. H_2SO_4 made up to one litre).
- Mix the above three reagents well and make up the volume to two litres.

Reagent B

Dissolve 1.056 g of ascorbic acid in 200 ml of reagent A (prepare reagent B freshly every time).

Apparatus Required

Shaking bottle (100ml); Mechanical shaker; Pipette; Volumetric flask (25 ml) ; Filter paper No.40 and Photo electric colorimeter.

Procedure

- ❖ Weigh accurately 5 g of soil and transfer to a polythene-shaking bottle.
- ❖ Add 50 ml of Bray 1 extractant.
- ❖ Shake the contents in a reciprocating mechanical shaker for one minute.
- ❖ Filter the contents through Whatman No. 40 filter paper (the filtrate should be clean and colorless).
- ❖ Pipette out exactly 5 ml of the sample solution in 25 ml of volumetric flask
- ❖ Add 4 ml of reagent B
- ❖ Make up the volume to 25 ml with distilled water.
- ❖ Shake the contents and allow for few minutes for colour development.
- ❖ Measure the intensity of blue colour in photoelectric colorimeter using a red filter at 660 nm.
- ❖ Simultaneously run a blank also for calibrating the instrument.
- ❖ Using the standard curve, find out the concentration of P (ppm) and calculate the available P content.

Preparation of standard curve for available P estimation

Preparation of 1 litre of 100 ppm P stock solution

One mg of solute in a litre of solution is 1 ppm solution. For 100-ppm solution, 100 mg of P is to be dissolved in 1 litre solution. 0.439 g of KH_2PO_4 is to be dissolved in one litre of water to prepare one litre of 100 ppm P solution. This can be used as stock solution.

Preparation of working standards

Pipette out 10 ml of this solution and make up to 100 ml with distilled water to get 10 ppm solution. From this solution the following working standards can be prepared.

Volume to be pipetted out from 10 ppm solution	Volume to be made up	Working standard (ppm)
0.5 ml	25 ml	0.2
1.0 ml	25 ml	0.4
1.5 ml	25 ml	0.6
2.0 ml	25 ml	0.8
2.5 ml	25 ml	1.0

As in the above table, prepare a series of concentrations of P solutions by transferring into 25 ml volumetric flasks, 0.5, 1.0, 1.5, 2.0, 2.5 ml of 10 ppm solution which on dilution to 25 ml will give 0.2, 0.4, 0.6, 0.8 and 1.0 ppm working standard solution of P respectively. After pipetting the above aliquots of 10 ppm in the respective 25 ml volumetric flasks, add 5 ml of Olsen reagent, (0.5 M NaHCO₃ pH adjusted to 8.5) in case the standard curve is meant for available P estimation by Olsen's method or 5 ml of Bray's No.1 extractant (0.03 N NH₄F and 0.025 N HCl) in case of the Bray's method. Develop the color by adding 4 ml of Reagent B and measure the color intensity in the colorimeter as done in the case of soil extracts. Plot the values of absorbance against the concentration of P and use it as standard curve for finding out the concentration of P in the soil extract.

Calculation

Weight of the soil taken	= 5g
Volume of Bray No.1 extractant used for extraction	= 50 ml
Volume of extracted solution used for P estimation (aliquot)	= 5 ml
Colorimeter reading	= T
Concentration of P read from standard graph corresponding to the percent transmittance	= X ppm or $X / 10^6$ g /ml
Therefore amount of available P in soil	$X \frac{50}{10^6} \times \frac{25}{5} \times 2.24 \times 10^6 \text{ kg ha}^{-1}$

Estimation of Available Phosphorus in Soil

(Olsen’s method for neutral, alkaline and calcareous soils)

Principle

Phosphorus is extracted from the soil with 0.5 M NaHCO₃ adjusted to pH 8.5. Blue colour is developed by ascorbic acid method. The intensity of colour is measured in a photoelectric colorimeter.

Reagents required

- 0.5 M NaHCO₃ (pH 8.5): (42 g of NaHCO₃ dissolved in one litre of water).
- Darco G 60 or activated carbon (free of phosphorus).
- Ascorbic acid

Reagent A

- As in Bray No 1 method

Reagent B

- Dissolve 1.056 g of ascorbic acid in 200 ml of reagent A (prepare reagent B freshly every time)

Apparatus Required

- Shaking bottle (100ml)
- Mechanical shaker
- Pipette
- Volumetric flask (25 ml)
- Filter paper No.40 and
- Photoelectric colorimeter.

Procedure

- Weigh accurately 5 g of soil and transfer to a polythene-shaking bottle.
- Add 50 ml of 0.5 M NaHCO_3 (pH 8.5) and a pinch of Darco G.60 (to make the extraction colorless).
- Shake the contents in a reciprocating mechanical shaker for 30 minutes.
- Filter the contents through Whatman No. 40 filter paper (the filtrate should be clean and colorless).
- Pipette out 5 ml of the solution in 25 ml of volumetric flask
- Add 4 ml of reagent B
- Make up the volume to 25 ml with distilled water.
- Shake the contents and allow for few minutes for colour development.
- Measure the intensity of blue colour in photoelectric colorimeter using a red filter at 660 nm.

- Simultaneously run a blank also for calibrating the instrument.
- Using the standard curve, find out the concentration of P (ppm) and calculate the available P content.

Preparation of standard curve for available P estimation

As in Bray -1 method

Calculation

Weight of the soil taken = 5 g

Volume of NaHCO₃ used for extraction = 50 ml

Volume of extractant solution used for = 5 ml

P estimation (aliquot)

Colorimeter reading = T

Concentration of P read from standard = X ppm or X /10⁶ g /ml

graph corresponding to the % transmittance

Therefore amount of available P in soil = $\frac{X}{10^6} \times \frac{50}{5} \times \frac{25}{5} \times 2.24 \times 10^6 \text{ kg ha}^{-1}$

Result

Exercise.10

Estimation of Available Potassium in Soil

(Neutral Normal ammonium acetate method using Flame Photometer)

Principle

The K ions in the exchange sites are replaced with NH_4^+ , which releases K^+ . The concentration of K ions in the solution is then determined using Flame photometer.

Reagents required

- N ammonium acetate (Neutral in pH) Dissolve 77 g of AR grade ammonium acetate ($\text{CH}_3\text{COONH}_4$) in 1000 ml of distilled water. Adjust the pH to 7.0.

Apparatus Required

- Injection vials
- Filter paper No. 40
- Funnel
- Flame photometer

Procedure

- ❖ Transfer 5 g of soil into a 100ml polythene-shaking bottle. Add 25 ml of neutral normal ammonium acetate and shake the content in a mechanical reciprocating shaker for 5 minutes.
- ❖ Filter the contents through Whatman No. 40 filter paper.
- ❖ Feed the filtrate into the flame photometer and record the reading.
- ❖ Calculate the available K content using a standard curve.

Preparation of Standard solution

Accurately weigh 1.907 g of KCl (previously dried for 2 hours at 105°C .) Transfer it to a 1000 ml volumetric flask and make up the volume. This solution gives 1000 ppm K. From this 1000 ppm K solution (stock solution A) pipette out 100 ml into a 1000 ml volumetric flask, dilute with distilled water and make up the volume. This

solution gives 100 ppm K. (stock solution B). From this 100 ppm K solution, various standards are prepared ranging from 10 to 100 ppm K as given below.

Concentration required	Volume to be pipetted from stock solution B	Volume to be made up
10 ppm	10 ml	100 ml
20 ppm	20 ml	100 ml
30 ppm	30 ml	100 ml
40 ppm	40 ml	100 ml
50 ppm	50ml	100 ml
60 ppm	60 ml	100 ml
70 ppm	70 ml	100 ml
80 ppm	80 ml	100 ml
90 ppm	90 ml	100 ml
100 ppm	100 ml	100 ml

Adjust the galvanometer to read zero for blank and 100 for 100 ppm K solution. Then introduce the standards and record the readings. Construct the standard curve with the readings recorded for various standard solutions.

Operational Instructions for EEL flame photometer

- ❖ Turn the sensitivity control fully anti clockwise.
- ❖ Select and insert the appropriate optical filter.
- ❖ Move aside the mica window and insert a lighter above the burners.

- ❖ Turn on the air supply. Adjust the air control to give a reading of 8-10 lb .per square inch on the pressure gauge.
- ❖ Turn on the gas supply and light the flame. Withdraw the lighter and close the window.
- ❖ Slide a beaker of distilled water in to the sample recess
- ❖ With the distilled water still in position, slowly close the gas control until the separate blue cones set in. Little if any readjustment should be necessary for subsequent operation. Do not adjust the gas supply to alter the sensitivity of the instrument.
- ❖ Set the instrument to read zero by means of zero control against blank solution.
- ❖ Replace the blank by a standard solution of the concentration corresponding to a reading of 100 on the calibration curve in use and adjust the sensitivity control to give approximately 100.
- ❖ Reset the zero against the blank solution.
- ❖ Again present the solution and set the sensitivity control to give exactly 100. Check this setting from time to time during a series of tests.
- ❖ Check the zero reading with reagent blank.
- ❖ Proceed with determination of the sample.
- ❖ Before close down operate the instrument using the distilled water until the reading returns to zero.

Calculation

Weight of the soil taken = 5 g

Volume of extractant used = 25 ml

Flame photometer reading = T

Concentration of K in the standard = X ppm or X microgram / ml
curve for T

Therefore amount of available K in the soil
$$= \frac{X}{10^6} \times \frac{25}{5} \times 2.24 \times 10^6 \text{ kg ha}^{-1}$$

Result

Exercise.11

Estimation of Available Micronutrients in Soil

(Fe, Mn, Zn and Cu by Atomic Absorption Spectrometer)

Several extractants have been tried to extract and estimate the available micronutrient status of the soil. Of these the Diethylene Triamine Penta Acetic Acid (DTPA) was found to be the most suitable extractant for estimating the available Fe, Mn, Zn, and Cu by the use of Atomic Absorption Spectrophotometer.

Principle

DTPA forms stable complexes with Fe, Mn, Zn and Cu. Its capacity to complex each of the micronutrient cation is 10 times its atomic weight. Always use glass distilled water.

Reagents required

- (i). DTPA (0.005 M).
- (ii). $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ – 0.01 M solution
- (iii). Triethanolamine: (0.1 M solution) TEA suppresses the solubility of CaCO_3 , which will release the occluded micronutrients (unavailable to the plant).

The DTPA extractant solution is prepared by dissolving 13.1 ml of TEA, 1.967 of AR grade DTPA and 1.47 g of CaCl_2 in 100 ml glass distilled water. The contents are allowed for some time so that the DTPA will dissolve and then diluted to about 900 ml. The pH of the solution is adjusted to 7.3 ± 0.05 with 1:1 HCl by stirring and the volume made up to 1 litre.

Zinc

0.439 g of AR grade $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ is dissolved in 200 ml glass distilled water in a beaker to which 5 ml of 1:5 H_2SO_4 is added. The contents are transferred to a one litre volumetric flask and the volume made up. This gives 100 ppm of Zn. From this stock solution working standards of 0, 0.1, 0.2, 0.4 and 0.6 $\mu\text{g/ml}$ (ppm) solutions are prepared.

Iron

0.702 g of AR grade ferrous ammonium sulphate dissolved along with 5 ml of 1:5 H_2SO_4 and made up to 1 litre gives 100 ppm of Fe stock solution. From this stock solution various concentrations of working standards *viz.*, 0, 1, 2, 4, 6 ppm are prepared.

Manganese

0.288 g of AR grade potassium permanganate is dissolved in 300 ml of glass-distilled water. To this 20 ml of conc. H_2SO_4 is added and warmed to 60°C . Then oxalic acid is added drop by drop to make the solution colorless. The contents are cooled and made up to 1 litre, which gives 100-ppm stock solution. From this, working standards of 0, 1, 2, 4, 6, 8 ppm are prepared.

Copper

0.392 g of AR grade $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$ dissolved in glass-distilled water and made up to 1 litre gives 100 ppm of Cu. From these working standards of 0, 1, 2, 4, 6-ppm solutions are prepared.

From the working standard solution, prepare standard curve for each nutrient. While feeding the standards, first start from the lowest concentration just after standardizing the instrument with blank solution. In between two standard solutions, introduce the blank and ensure that there is no change in the zero point. Prepare a graph by plotting the absorbance values against concentrations.

Estimation of the nutrient concentrations

- ❖ Transfer 10 g of air-dried soil sample to 150 ml conical flask / polythene bottle and add 20 ml of the DTPA extractant solution.
- ❖ Close the bottle and shake for 2 hours in a horizontal shaker
- ❖ Filter through what man No. 42 filter paper.
- ❖ Take the reading of the filtrate in the Atomic Absorption Spectrophotometer and by referring to the standard curve calculate the concentration of each micronutrient in the sample. Shaking time, concentration and pH of the

DTPA extractant and temperature will influence the quantity of nutrients extracted.

Calculation

Weight of the soil taken = 10 g

Volume of extractant used = 20 ml

AAS reading = y

Concentration of micronutrients

(eg. Fe) in the standard curve for y = X ppm or X microgram / ml

Therefore amount of available
micronutrients (eg. Fe) in the soil

$$= \frac{X}{10^6} \times \frac{20}{10} \times 10^6 \text{ ppm}$$

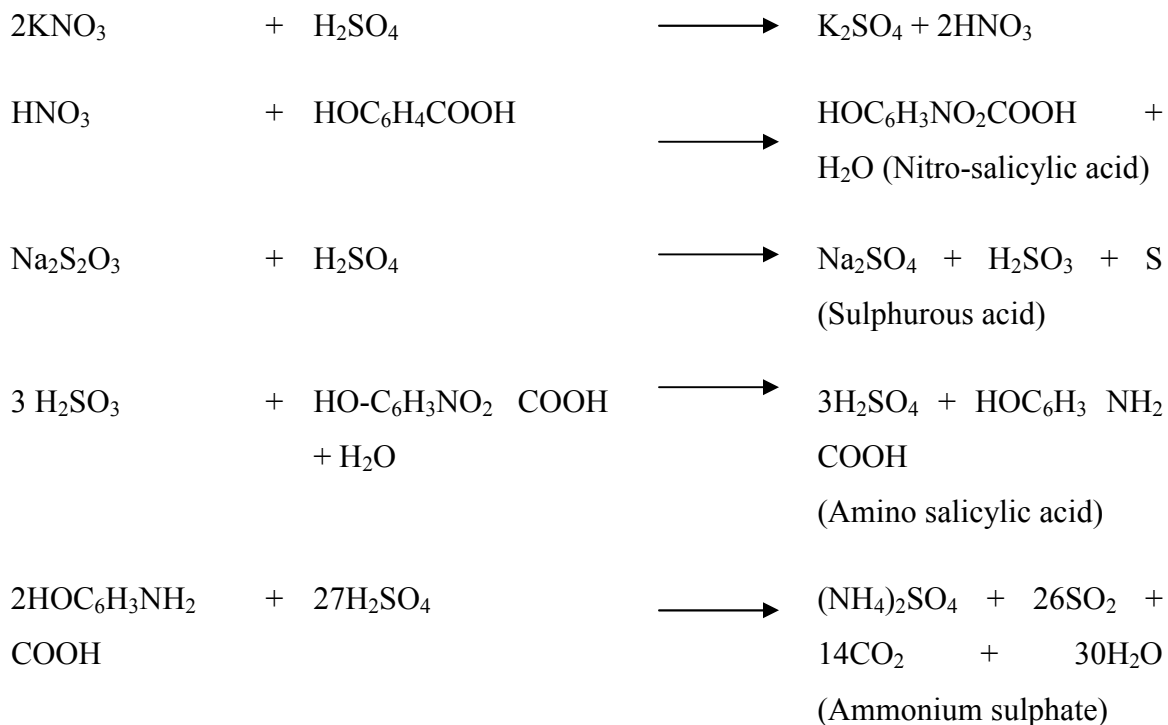
Result

Note:

Normally the extractable boron (B) and Molybdenum (Mo) in soil are not done by AAS. They are determined using colorimeter or UV Spectrophotometer. Boron and Mo are extracted from soil by following hot water soluble method (Berger & Tray, 1939) and ammonium oxalate method (Gregg, 1953) respectively.

Exercise.12**Estimation of Nitrogen in Plant Sample****Principle**

The nitrogenous compounds are reduced to ammonia by salicylic acid which is converted into ammonium sulphate by digestion with concentrated sulphuric acid. The digested material containing ammonium sulphate is distilled with excess alkali and the distillate is collected in 2 per cent boric acid containing double indicator and the same is titrated with standard acid. From this, the nitrogen content is found out.

Reactions**Reagents required**

1. Sulphuric acid – Salicylic acid mixture – 300 ml of cone. H_2SO_4 + 10 g of pure salicylic acid.
2. Catalyst mixture – Potassium sulphate and copper sulphate in the ratio of 10:1. Grind each separately and mix together.

3. Sodium thiosulphate
4. 40% sodium hydroxide – 40 g NaOH in 100 ml water
5. Sodium sulphide 10% solution 10 g sodium sulphide in 100 ml distilled water.
6. Double indicator – Bromocresol green 0.5 g and methyl red 0.1 g in 100 ml of alcohol. pH adjusted to 4.2 using 0.1 N NaOH.
7. 0.1 N sulphuric acid (Standard acid).

Procedure

Digestion

Weigh about 0.5 to 1.0 g of plant sample and transfer it to a 500 ml kjeldahl digestion flask. Add 30 ml of sulphuric acid – Salicylic acid mixture. Shake the contents for 2 to 3 minutes and then allow it to react in cold for half an hour. This treatment leads to the formation of a nitro compound as a result of combination of the nitrate with salicylic acid. To the mixture add 5 g of sodium thiosulphate. This reduces the nitro group to form amino salicylic acid. This amino salicylic acid is converted to ammonium sulphate by the sulphuric acid.

Add 10 g of catalyst mixture, shake the flask and mix the contents well. Heat the mixture gently until the frothing ceases and then boil briskly. Continue the digestion till the digest becomes clearly green. After the completion of the digestion add 50 to 100 ml of distilled water.

Distillation

Transfer the diluted digest to a distillation flask. Wash the digestion flask and transfer the wash to the distillation flask, each time with distilled water for about 5 times, to ensure complete transfer of digested material to the distillation flask. Add a few pieces of zinc granules to increase the boiling point and porcelain pieces to prevent bumping. Dilute the contents of the flask to a volume of 500 ml.

Take 20 ml of 2% boric acid containing double indicator by using measuring cylinder in a 500 ml ice tumbler or tall form beaker and add a drop of double indicator.

Keeps the ice tumbler at the delivery end of distillation set immersing the tip in the boric acid.

Add 120 ml of 40% NaOH and 10 ml of sodium sulphide solution to the distillation flask distill till 100 ml of the distillate are collected in about an hour. Test for the completion of distillation by testing the distillate with a piece of moist red litmus paper. Absence of blue colour indicates that all the ammonia has been distilled. Then disconnect the delivery tube and wash the delivery end with distilled water and collect the washings in the ice tumbler. Titrate the contents with 0.1 N H₂SO₄. The end point is the change of green to wine red colour.

Calculation

Weight of the plant sample taken = W g

Volume of 0.1 N H₂SO₄ consumed during titration = V ml

1 ml 0.1 N H₂SO₄ is equal to .0014 g of N

Therefore V ml of 0.1 N H₂SO₄ is = V x 0.0014 g of N

This is present in W g of plant sample

Therefore percentage of nitrogen in the plant sample = $V \times 0.0014 \times 100 / W$

Result

Exercise.13

Estimation of Phosphorus and Potassium in Plant Sample

1. Tri-acid extracts preparation

The tri-acid extract of plant material is prepared for the estimation of total P, K, Ca, Mg and micronutrients.

Principle

A known weight of the plant sample is digested with triple acid to destroy the organic fractions and to bring the mineral constituents into solution.

Reagents Required

1. Triple acid mixture – 9:2:1 ratio of conc. nitric acid, conc. sulphuric acid and perchloric acid.

Procedure

Weigh about one g of the given plant sample into a 100 ml conical flask. Add 15 ml of the triple acid mixture and cover the mouth of the flask with funnel and digest the contents over a sand bath till a clear colourless solution is obtained. Dilute with distilled water and transfer to a 100 ml volumetric flask. Wash the conical flask with small increments of water and add the washings to the volumetric flask. Make up the volume to 100 ml with distilled water and reserve it for further analysis.

2. Estimation of phosphorus

Principle

When vanadomolybdate and phosphate radical react in nitric acid medium a heteropoly compound is formed which is yellow in colour. The intensity of yellow colour is proportional to the amount of phosphorus in the sample. By reading the intensity of yellow colour produced in a spectrophotometer at 470 nm the amount of phosphorus in the sample is determined.

Reagents

Barton's reagent: It is prepared by dissolving 25 g ammonium molybdate in 400 ml of distilled water and mixing this with a solution containing 1.25 g ammonium meta vanadate dissolved in 300 ml concentrated nitric acid and making up the volume to one litre.

Procedure

Pipette out 5 ml of tri-acid extract into 25 ml volumetric flask. Add 5 ml of Barton's reagent, shake well and make up the volume to 25 ml and make it a homogeneous solution. Allow about 30 minutes for the colour to develop. Read the intensity of yellow colour developed in a spectrophotometer at 470 nm. By referring to the standard curve prepared (as explained in practical class – 9, Separate standard curve for yellow colour is to be prepared using Barton's reagent) calculate the phosphorus content of the plant sample.

Calculation

Weight of the sample taken	= W g
Volume of tri-acid extract prepared	= 100 ml
Volume of aliquot taken for colour development	= 5 ml
Volume made up after colour development	= 25 ml
Concentration of the solution as read from the spectrophotometer	= X ppm
Therefore percentage of P in the sample	= $X / 10^6 \times 25 / 5 \times 100 \times 100 / W$

Result

3. Estimation of potassium

Principle

Potassium in solution is atomized to flame and the flame excites atom of potassium causing them to emit radiation at specific wavelength. The amount of radiation emitted is directly proportional to concentration of the solution and it is measured in a flame photometer with suitable filter, which transmits only potassium wavelength (768 n.m red filter).

Procedure

Preparation of Standard Graph

Transfer 10 ml of 1000-ppm K solution into 100 ml standard flask and make up the volume. That gives 100 ppm of potassium. From that, prepare solutions containing 10, 20, 30..... 90 ppm potassium by pipeting out 10, 20, 30..... 90 ml of 100-ppm solution and make up the volume to 100 ml. The flame photometer is calibrated by feeding the standards as mentioned in the exercise 10. The graph is inbuilt in present models. Introduce the tri-acid extract in the flame photometer and get concentration of potassium and expressed in per cent.

Calculation

Weight of the sample taken	= W g
Volume of tri-acid extract prepared	= 100 ml
Flame photometer reading	= T
Concentration of K in the standard curve for recorded T	= X ppm
Concentration of K in per cent	= $X / 10^6 \times 100/w \times 100$

Result

Exercise.14

Estimation of Fe, Mn, Zn and Cu in Plant Sample

(Atomic Absorption Spectrophotometer method)

1. Tri-acid extract preparation

The tri-acid extract of plant material is prepared for the estimation of total P, K, Ca, Mg and micronutrients.

Principle

A known weight of the plant sample is digested with triple acid to destroy the organic fractions and to bring the mineral constituents into solution.

Reagents Required

1. Triple acid mixture – 9:2:1 ratio of conc. nitric acid, conc. sulphuric acid and perchloric acid.

Procedure

Weigh about one g of the given plant sample into a 100 ml conical flask. Add 15 ml of the triple acid mixture and cover the mouth of the flask and digest the contents over a sand bath till a clear colourless solution is obtained. Dilute with distilled water and transfer to a 100 ml volumetric flask. Wash the conical flask with small increments of water and add the washings to the volumetric flask. Make up the volume to 100 ml with distilled water and reserve it for further analysis.

2. Estimation of micronutrients (Fe, Mn, Zn and Cu):

Iron

0.702 g of AR grade ferrous ammonium sulphate dissolved along with 5 ml of 1:5 H_2SO_4 and made up to 1 litre gives 100 ppm of Fe stock solution. From this stock solution various concentrations of working standards *viz.*, 0, 1, 2, 4, 6 ppm are prepared.

Manganese

0.288 g of AR grade potassium permanganate is dissolved in 300 ml of glass-distilled water. To this 20 ml of conc. H_2SO_4 is added and warmed to 60°C . Then oxalic acid is added drop by drop to make the solution colorless. The contents are cooled and made up to 1 litre, which gives 100-ppm stock solution. From this, working standards of 0, 1, 2, 4, 6, 8 ppm are prepared.

Zinc

0.439 g of AR grade $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ is dissolved in 200 ml glass distilled water in a beaker to which 5 ml of 1:5 H_2SO_4 is added. The contents are transferred to a one litre volumetric flask and the volume made up. This gives 100 ppm of Zn. From this stock solution working standards of 0, 0.1, 0.2, 0.4 and 0.6 $\mu\text{g/ml}$ (ppm) solutions are prepared.

Copper

0.392 g of AR grade $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ dissolved in glass-distilled water and made up to 1 litre gives 100 ppm of Cu. From these working standards of 0, 1, 2, 4, 6-ppm solutions are prepared.

From the working standard solution, prepare standard curve for each nutrient. While feeding the standards, first start from the lowest concentration just after standardizing the instrument with blank solution. In between two standard solutions, introduce the blank and ensure that there is no change in the zero point. Prepare a graph by plotting the absorbance values against concentrations.

Estimation of the nutrient concentrations

Take the reading in the Atomic Absorption Spectrophotometer by feeding the tri-acid extract and by referring to the standard curve, calculate the concentration of each micronutrient in the sample.

Calculation

Weight of the soil taken = W g

Volume of tri-acid extract made up to = 100 ml

AAS reading = y

Concentration of micronutrients

(eg. Fe) in the standard curve for y = X ppm

Therefore micronutrient (eg. Fe) content
in the plant sample

= X x 100 / W ppm

Result

Exercise.15**Estimation of Anions in Irrigation Water Sample****Collection of irrigation water sample for analysis**

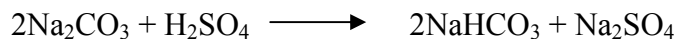
Samples of water intended for chemical examination on their suitability or otherwise for irrigation may be collected as directed below:

Collect nearly half a gallon of water in a clean colorless glass bottle having a well-fitted glass stopper. Rinse the bottle thoroughly at least three times with the water sample before the sample is finally drawn. When water is collected from a pipe or tap, allow the water to run waste for a couple of minutes before the sample is drawn. On no account should the sample of water come in touch with the hand. Stopper the bottle tightly and label it properly stating the source of water, date and time of collection of sample. At the time of analysis, filter the sample through a dry filter paper, to eliminate suspended impurities and carry out the chemical analysis on suitable aliquots for the anions and cations.

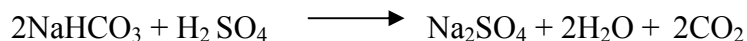
1. Estimation of carbonates and bicarbonates**Principle**

Carbonates and bicarbonates in solution can be determined by titrating the solution with standard sulphuric acid (0.1 N) using phenolphthalein and later methyl orange indicators.

The titre value with phenolphthalein represents the quantitative conversion of the carbonates into bicarbonates as shown by the equation.



The titre value with methyl orange represents the neutralization of the bicarbonate originally present in the solution plus the bicarbonate resulted from the conversion of carbonate present in the solution to the stage of bicarbonate as per the above equation. This may be represented as per the following equation.



Hence the titer value of CO_3 will be twice the value for phenolphthalein. The titre value for HCO_3 will be equal to the value with methyl orange minus the value with phenolphthalein. The titration with methyl orange is continued after the titration with phenolphthalein without refilling the burette.

Reagents Required

1. Standard sulphuric acid (0.1 N); 2. Phenolphthalein indicator and 3. methyl orange indicator

Procedure

Pipette out 25 ml of water sample into a 250 ml conical flask. Add a drop of phenolphthalein and the solution attains pink colour. Presence of pink colour shows the presence of carbonate in the water sample. Absence of pink colour shows the absence of carbonate in the water sample. Titrate this against N/10 H_2SO_4 from a burette till the pink colour disappears. Note down the titer value ('V' ml). This represents the volume of N/10 H_2SO_4 required to neutralize half the amount of carbonate present in 25 ml of the water sample.

To the colorless solution obtained above, add a drop of methyl orange and the solution attains light yellow colour. Titrate this against N/10 H_2SO_4 till the colour changes to pinkish red. Note down the titer value (' V_1 ' ml). This value represents the volume of N/10 H_2SO_4 required to neutralize the bicarbonate originally present and that from the conversion of carbonate.

Calculate the separate amounts of carbonate and bicarbonate and express the result as milli equivalent/liter.

Calculation

Carbonate

Volume of N/10 H_2SO_4

required to neutralize half of the carbonate = V ml

Therefore volume of N/10 H_2SO_4 required to

neutralize the entire carbonate = $2 \times V = 2V$ ml.

$$\begin{aligned}
 1 \text{ ml of N/10 H}_2\text{SO}_4 &= 0.003 \text{ g of CO}_3 \\
 \text{Therefore } 2V \text{ ml of N/10 H}_2\text{SO}_4 &= 0.003 \times 2V \text{ g of CO}_3 \\
 25 \text{ ml of water sample contains} &= 0.003 \times 2V \text{ g of CO}_3 \\
 \text{Therefore carbonate content in ppm} &= 0.003 \times 2V \times 1000 \times 1000/25 \\
 \text{milli equivalents of CO}_3 \text{ per litre} &= \text{ppm} / 30
 \end{aligned}$$

Bicarbonate

Volume of N/10 H₂SO₄ required to neutralize the full bicarbonate originally present + the bicarbonate resulted from carbonate = V₁ ml

Volume of N/10 H₂SO₄ required to neutralize the half of the carbonate = V ml

Therefore volume of N/10 H₂SO₄ required to neutralize the bicarbonate originally present = (V₁-V) ml

1ml of N/10 H₂SO₄ = 0.0061g of HCO₃⁻

Therefore (V-V₁) ml of H₂SO₄ = 0.0061 x (V-V₁)g of HCO₃⁻

25 ml of water sample contains = 0.0061 x (V-V₁) g of HCO₃⁻

Therefore bicarbonate content in ppm = 0.0061 x (V-V₁) x 1000 x 1000/25

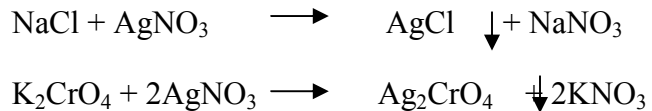
milli equivalents of HCO₃⁻ per litre = ppm / 61

Result

2. Estimation of chloride

Principle

Chloride ions in water sample can be determined by titration with standard silver nitrate solution using potassium chromate as an indicator. By addition of AgNO_3 all the chloride is precipitated as silver chloride and any further addition of AgNO_3 produces a flesh red colour precipitate of silver chromate, which is the end point of the titration.



Reagents Required

1. 0.1 N AgNO_3 ; 2. K_2CrO_4 indicator

Procedure

Pipette out 25 ml of water sample into a porcelain basin. Add few drops of K_2CrO_4 indicator solution. Titrate against 0.1 N AgNO_3 with constant stirring by means of a glass rod until the addition of a drop produces flesh red coloration throughout the mixture in the basin. Note down the titre value (Vml)

Calculation

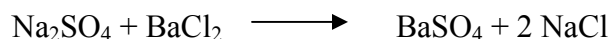
Volume of 0.1 N AgNO_3 consumed	= V ml
1 ml of N/10 AgNO_3	= 0.00355 g of chloride
25 ml of water sample contains	= 0.00355 x V g of chloride
Therefore chloride content in ppm	= 0.00355 x V x 1000 x 1000/25
In terms of milli equivalents per liter	= ppm/35.5

Result

3. Estimation of sulphate

Principle

Sulphate in water sample is precipitated as barium sulphate by the addition of barium chloride in acid medium. The precipitate is filtered, washed free of chloride, ignited and weighed as barium sulphate.



Reagents Required

1. Dilute hydrochloric acid; 2. Solid NH_4Cl and 3. Barium chloride

Procedure

Pipette out 50 ml of water sample into a 400 ml beaker. To that add 10 ml of dilute hydrochloric acid and 1 gm of solid NH_4Cl . The contents of the beaker are boiled and 10 ml of barium chloride is added drop by drop with simultaneous stirring. Then boiling is continued for another 2-3 minutes and the precipitate is allowed to settle. The completion of precipitation is tested by adding small quantity of barium chloride along the sides of the beaker. The beaker is kept on a sand bath for half an hour to promote granulation. The precipitate is filtered through Whatman No.42 filter paper and washed with hot water till the filtrate runs free of chloride. Transfer the filter paper along with the precipitate to a weighed silica basin. Then dry the contents in an electric oven and ignite over the flame. Cool the silica basin with the ash. The ignition is continued followed by cooling and weighing till a constant weight is attained.

Calculation

Volume of the water sample taken = 50 ml

Weight of empty silica basin = W_1

Weight of silica basin + ash = W_2

Weight of BaSO_4 alone = $W_2 - W_1$

233.3 g of BaSO_4 contains 96.06 g of Sulphate

Therefore $(W_2 - W_1)$ g of BaSO_4 contains $= 96.06/233.4 \times (W_2 - W_1)$ g of BaSO_4

This is present in 50 ml of the sample

Therefore chloride content in ppm $= 96.06/233.4 \times (W_2 - W_1) \times 10^6/50$

In terms of milli equivalent per liter $= \text{ppm} / 48.03$

Result

Exercise.16**Estimation of Cations in Irrigation Water Sample****1. Estimation of calcium and magnesium****Principle**

Calcium and magnesium get complexed by EDTA in the order Ca first and Mg afterwards. In this experiment Ca is estimated first by using an indicator murexide at pH 12 in the presence of sodium hydroxide. Then Ca + Mg is estimated by using an indicator Eriochrome Black-T at pH 10 in the presence of ammonium chloride and ammonium hydroxide buffer solution.

Reagents Required

1. 0.02N EDTA; 2. murexide indicator; 3. 10% Sodium hydroxide; 4. $\text{NH}_4\text{Cl-NH}_4\text{OH}$ Buffer solution and 5. Eriochrome Black-T indicator

Procedure**Calcium**

Pipette out 25 ml of irrigation water sample into a porcelain basin. Add 10% Sodium hydroxide solution drop by drop to neutralize the acidity if any (use litmus paper) and add another 5 ml excess to maintain the pH at 12. Add a pinch (50 mg) of murexide indicator and titrate with 0.02N EDTA till the colour changes from pinkish red to purple or violet.

Calcium + Magnesium

Pipette out 25 ml of irrigation water sample into porcelain basin. Add buffer solution drop by drop to neutralize the acidity if any (use litmus paper) and 5 ml excess to maintain the pH at 10. Add 2-3 drops of Eriochrome Black-T indicator solution and titrate with 0.02N EDTA till the colour changes from purple red to sky blue.

Calculation

Volume of 0.02N EDTA used in the titration

for Calcium + Magnesium = 'X' ml

Volume of 0.02 N EDTA used for Calcium = 'Y' ml

Therefore volume of 0.02N EDTA used for

Magnesium alone = (X-Y) ml

Ca alone

1ml of 0.02N EDTA = 0.0004 g of Ca

Therefore Y ml of 0.02N EDTA = 0.0004 x Yg of Ca

This is present in 25 ml of water sample

Therefore in 10^6 ml of water sample (ppm) = $0.0004 \times Y/25 \times 10^6$

In terms of milli equivalent per litre = ppm/20 of Ca

Mg alone

1ml of 0.02N EDTA = 0.00024 g of Mg

Therefore (X-Y) ml of 0.02 N EDTA = 0.00024 x (X-Y)g of Mg.

This is present in 25 ml of water sample

Therefore 10^6 ml of water sample (ppm) = $0.00024 (X-Y)/25 \times 10^6$

In terms of milli equivalent per liter = ppm/12

Result

2. Estimation of sodium

Principle

Sodium in solution is atomized in flame and the flame excites atoms of sodium causing them to emit radiation at specific wavelength. The amount of radiation is proportional to the concentration of the solution and it is measured in a flame photometer by suitable filter, which transmits only sodium wavelength (580nm).

Procedure

Preparation of Standard Graph

Transfer 10 ml of 1000-ppm Na solution into 100 ml standard flask and make up the volume. That gives 100 ppm of Sodium. From that, prepare solutions containing 10, 20, 30..... 90 ppm Sodium by pipeting out 10, 20, 30..... 90 ml of 100-ppm solution and make up the volume to 100 ml. The flame photometer is calibrated by feeding the standards. The graph is inbuilt in present models. Introduce the irrigation water sample in the flame photometer and get concentration of sodium and expressed in me/lit.

Calculation

Flame photometer reading	= T
Concentration of Na in the standard	= X ppm
curve for T	
Concentration of Na in m.e./litre	= X ppm / 23

Result

Estimation of potassium

Principle

Potassium in solution is atomized to flame and the flame excites atom of potassium causing them to emit radiation at specific wavelength. The amount of radiation emitted is directly proportional to concentration of K present in the solution and it is measured in a flame photometer with suitable filter, which transmits only potassium wavelength (768nm red filter).

Procedure

Preparation of Standard Graph

Transfer 10 ml of 1000-ppm K solution into 100 ml standard flask and make up the volume. That gives 100 ppm of potassium. From that, prepare solutions containing 10, 20, 30..... 90 ppm potassium by pipeting out 10, 20, 30..... 90 ml of 100-ppm solution and make up the volume to 100 ml. The flame photometer is calibrated by feeding the standards. The graph is inbuilt in present models. Introduce the irrigation water sample in the flame photometer and get concentration of potassium and expressed in me/lit.

Calculation

Flame photometer reading	= T
Concentration of K in the standard curve for T	= X ppm
Concentration of K in m.e./litre	= X ppm / 39

Result

Exercise.17**Quality Assessment of Irrigation Waters**

The quality of irrigation water is evaluated, mainly by the quantity of dissolved salts, proportion of anions, monovalent and divalent cations, sodium adsorption ratio, residual sodium carbonate, potential salinity, specific ion toxicity, proportion of magnesium, calcium in water etc.

Assessment

Work out PS, PSI, SAR, SSP, RSC and PI using the results of practical classes 5, 15 and 16. Based on the values arrived assess the quality of irrigation water.

1. Salinity based on E.C – USDA system

< 250 μ .mhos/cm	: Low saline	: Good
250 – 750 μ .mhos/cm	: Medium saline	: Fair
750 – 2250 μ .mhos/cm	: High saline	: Poor
> 2250 μ .mhos/cm	: Very high saline	: Very poor

2. Potential Salinity (PS)

$$PS = \frac{1}{2} SO_4^{2-} + Cl^- \text{ me/lit}$$

PS of water	Soil type suitable
1 and 3 me/L	fine, medium and coarse textured soils
3 and 15 me/L	safely used in medium and coarse textured soils
15 and 20 me/L	safely used only in coarse textured soils

3. Puri's Salt Index (PSI)

$$PSI = (Total Na^+ - 24.5) - (Total Ca^{2+} - Ca \text{ as } CaCO_3) \times 4.85$$

PSI of water	suitability
negative	good quality and suitable for irrigation
positive	poor quality water and unsuitable for irrigation

4. Sodium Adsorption Ratio (SAR)

$$Sodium \ Adsorption \ Ratio \ (SAR) = \frac{Na}{\frac{\sqrt{Ca + Mg}}{2}}$$

SAR of water	suitability
<10	Low sodic water
10.1 – 18.0	Medium sodic water
18.1 – 26.0	High sodic water
> 26	Very high sodic water

5. Soluble Sodium Percentage (SSP)

$$SSP = \frac{Na}{Total \ Cations \ (Ca + Mg + K + Na)} \times 100$$

SSP of water	Suitability
< 60 per cent	good quality and suitable for irrigation
> 60 per cent	poor quality water and unsuitable for irrigation

6. Residual Sodium Carbonate (RSC)

$$\text{RSC} = (\text{CO}_3^{2-} + \text{HCO}_3^-) - (\text{Ca}^{2+} + \text{Mg}^{2+})$$

RSC of water	Suitability
<1.25 me/L	good quality water
1.25 – 2.5 me/L	fair quality water
>2.5 me/L	poor quality water and unsuitable for irrigation

7. Permeability Index (PI)

$$\text{PI} = \frac{\text{Na} + \text{HCO}_3}{\text{Ca} + \text{Mg} + \text{Na}} \times 100$$

$$\text{Ca} + \text{Mg} + \text{Na}$$

PI of water	Suitability
<60 per cent	good quality and suitable for irrigation
>60 per cent	poor quality water and unsuitable for irrigation

8. Combined Evaluation on the Basis of EC & SAR

United States Salinity Laboratory (Richards, 1954) published a semi logarithmic diagram, which rates water with respect to EC and SAR. Four classes of each salinity and SAR were divided as shown below in the table.

Salinity Hazard	Class	EC (m.mhos/cm)	Sodium Hazard	Class	SAR
Low	C1	< 0.250	Low	S1	< 10
Medium	C2	0.250 - 0.750	Medium	S2	10 – 18
High	C3	0.750 - 2.250	High	S3	18 – 26
Very high	C4	>2.250	Very high	S4	>26

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