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Mechanism of Nutrient Absorption and Soil Fertility Evaluation

Nutrient Absorption in Plants:

All field crops absorb nutrient ions from the soil solution through their roots. Hence, most of the nutrients enter the plant's root as ions. The process of absorption of nutrients by roots is called **root - uptake of nutrients.**

The various forms in which essential nutrient elements are absorbed by plants are given in the previous topic.

Carbon and oxygen are mainly absorbed by the plants from atmosphere. They also occur as carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions in soil. Water dissociates into H^+ and OH^- ions. All these ions are available to the absorbing root surface. Hence, some carbon and oxygen are absorbed by plant roots along with hydrogen (from water).

Some essential nutrients are absorbed by plants as cations whereas some are absorbed as anions.

The nutrient ions are transferred due to ion exchange across the interfaces of soil and root into the cellular structure of plant. The positively charged ions called cations such as $NH4^+$ and K^+ are absorbed in exchange for H^+ ions of the plants released to the soil. The negatively charged ions called anions such as NO_3^- and $H_2PO_4^-$ are absorbed in exchange for OH^- and HCO_3^- ions.

The cations and anions enter the plant independently. But a certain degree of selectivity is noticed in absorption of different nutrient ions is by the plants. For example, NH_4^+ and K^+ are taken up rapidly whereas Ca^{2+} and Mg^{2+} are absorbed at a lower rate. Cl^- and NO_2^- ions are absorbed faster than SO_4^{2-} and $H_2PO_4^-$ ions.

Nitrogen is the nutrient absorbed as cation (ammonium ion, NHS) as well as anion (nitrate ion, NO_3). Most plants use nitrogen in ammonium and nitrate forms equally in their early growth stages. But ammonium ion has proved superior in rice cultivation. Some plants like tomatoes and tobacco prefer NO_2 ions for absorption. Hence, the preferential absorption of NH_2 and NO_3 ions differs in different plant species. Hence, mobility of nutrients takes place in the form of ions from soil solution to the roots and other parts of the plants.

Mechanism of Nutrient Ion Absorption by Plant's Roots:

The plants absorb water and mineral salts by their roots system. The mechanism of uptake and transport of mineral salts in plants involves the following four steps:

- Movement of ions formed from solid particles to soil solution.
- Movement of ions from soil solution to root surface.

- ❖ Entry of ions into roots.
- ❖ Translocation of ions in plants.

➢ **Movement of ions to soil solution:** The solid particles of inorganic and organic compounds dissolve in water present in soil to form ions. These ions are dissolved in soil water form soil solution. The essential nutrients are present in soil solution as cations and anions.

The soil solution remains in dynamic equilibrium with solid particles. When there is absorption of mineral elements from the soil solution, the solid particles come in it to make up the deficiency. In this way, the renewal of soil solution takes place several times. The absorption of nutrient element from the soil by the plant roots depends upon its concentration in soil solution.

The movement of nutrient ions from soil solution to roots can be shown with the help of the following diagram:

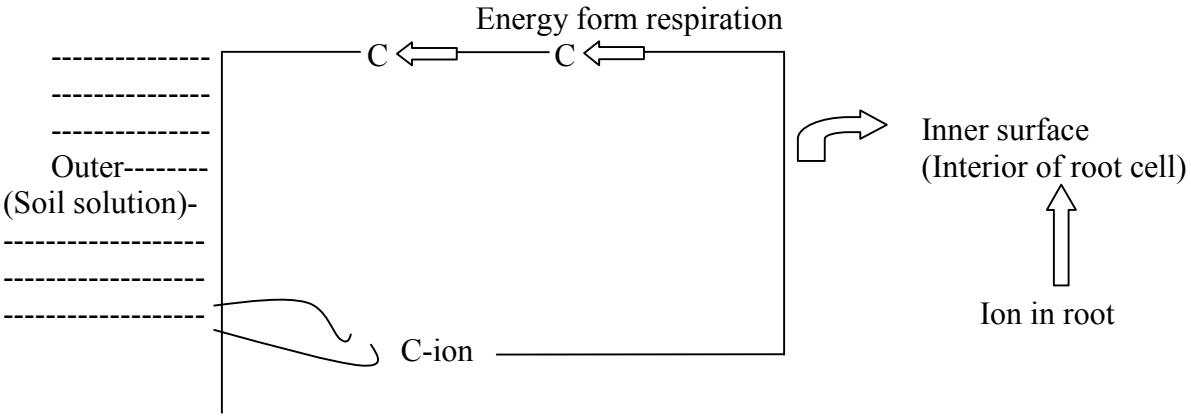


Fig: Absorption of nutrient ions by roots

➢ **Movement of ions from soil solution to root surface:** Plants absorb most nutrients from soil solution by their roots in the form of cations (positively charged ions) or anions (negatively charged ions). The plant nutrients are supplied to the roots by the following three ways:

- ❖ **Root interception:** The roots spread in soil and come in contact with soil colloids. Thus, the roots move towards the nutrients absorbed on soil colloids. This is called root interception. The role of root interception in the absorption of nutrient elements is very little because the root system comes in contact with only 1-3% of soil volume.
- ❖ **Mass flow:** Some nutrients move towards the roots along with water. These are absorbed by the plants for their growth. This movement is called mass flow. The nutrients which have comparatively high concentration in soil solution allow their sufficient amount to reach the root surface by mass flow. When the transpiration is more, the mass flow is also more. This mechanism is very important in case of absorption of N, Ca, Mg and S.
- ❖ **Diffusion:** Due to absorption of nutrients, the concentration of their ions near the roots decreases. Thus, the ions diffuse from soil solution towards the roots. The diffusion of ions in liquids takes place from a solution of higher concentration to a solution of lower concentration.

  Ordinarily, the rate of nutrient elements to reach across the roots surface is more. Hence, a concentration gradient is developed across the roots. Due to concentration gradient, the nutrient ions diffuse from a place of high concentration to a site of low concentration i.e., plant's root. This diffusion takes place till a new equilibrium is set up.

The rate of diffusion of an ion is expressed by **Fick's law** as follows:

$$F = -D \frac{dc}{dx}$$

Where F = Rate of diffusion
D = Diffusion constant

C = Concentration
x = Distance
de / dx = Concentration gradient

Thus, the nutrients with low concentration in soil solution are absorbed rapidly by the roots.

- **Entry of ions into roots:** There are two mechanisms known for the entry of nutrient ions into roots.
  - Passive absorption in which metabolic energy is not required.
  - Active absorption in which metabolic energy is needed.
    - ✓ **Passive absorption:** The main constituents of cell walls of epidermis of roots are cellulose tissues and pectic substances. The cellulose tissues act as sponge and allow diffusion of solution continuously. The volume of these tissues, in which solute ions diffuse according to concentration gradient, is called apparent free space. In passive absorption, the diffusion of ions takes place from soil solution to apparent free space. This process occurs due to concentration gradient without consuming any energy.

      According to modern concept, the entry of ions, in roots is by driving force caused due to electro - chemical potential. This potential depends upon the ratio of charges on concentration of solution and the ions present in it. The soil solution is neutral and cytoplasm present in cell membrane is negatively charged. In this way, a potential difference is generated which acts as a driving force to carry ions from soil solution in the plant passing through the cell membrane.

- **Active absorption:** The process of active nutrient absorption derives energy mainly from the oxidation of carbohydrates and other plant substances in respiration activities.

  It is considered that active absorption in cell membrane takes place with the help of a carrier present in it. Hence, this mechanism is termed as carrier theory. The carriers are the compounds produced in metabolic reactions. They combine with free ions to form carrier ion complex which can pass through the membrane and other barriers which are not permeable to free ions. The carrier ion complex decomposes on completion of transference. Thus, the ions from the epidermis (outer surface) of root enter the inner surface of the root cells.

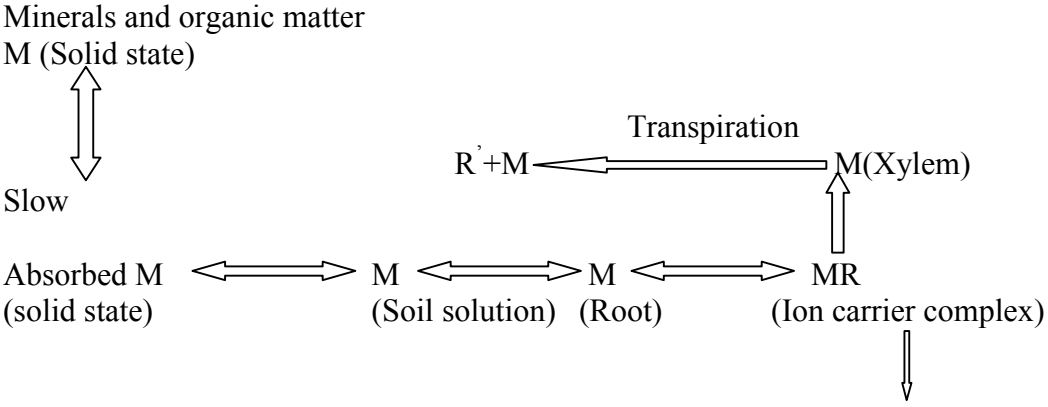
  The carrier molecules have specific binding sites for different ions. It causes selective absorption of ions. The energy is available for the formation of carrier in the form of ATP.

  After the completion of this circle, the ion diffuses inside the cell membrane and the carrier moves outside it where it starts the new circle for ion absorption.

  According to a concept, the main constituents of carriers are nucleoproteins, mitochondria and cytoplasm.

  Different ions have either different carriers or different binding surfaces. Some ions have competition for the same carrier site. For example, calcium and strontium have competition for the same carrier site whereas potassium does not have competition with them because its carrier is different.

  The modern mechanism of nutrient absorption by plants was established by Friad and Brushart in 1967. Its outlines are given as follows:



Absorption in outer surface ⟺ Passive absorption (outer absorption)

M(in root) ⟺ Active absorption
(Inner absorption in inner surface of roots by metabolic ion binding carriers)

(i) By diffusion
(ii) (ii) By mass flow
(iii) (iii) By ion exchange
(iv) M = Nutrient element ion
(v) MR = Ion carrier complex
(vi) R = Ion carrier
(vii) R '= Free carrier

Translocation of ions in plants: Nutrient ions move in xylem vessel after absorption by roots. From there, they are transported to stems and leaves with water. This transportation of ions with water is mainly due to mass flow. The rate of translocation of nutrient ions depends upon the rate of water absorption by roots and rate of transpiration. When the rate of transpiration of water by leaves is low, the rate of uptake of ions is also low. The transportation of nitrogen in xylem occurs in the form of nitrate, ammonium and amino acids.

Factors affecting Ion Absorption by Plants: The important factors that affect the ion absorption by plants are listed as under:

Factors related to soil	**Factors related to plants**
• Physical condition of soil	Nature of root system
• Availability of nutrient elements	Number of ion exchange sites at root surface
• Availability of water	Age and growth rate
• Temperature	Transpiration rate
• Soil pH	Respiration rate
• Concentration of other ions	

The factors that affection absorption in plants may be described briefly as follows:

❖ Factors related to soil:

- ✓ **Physical condition of soil:** Due to improper soil structure, a hard layer is formed beneath the soil surface or lumps are formed in the soil of the field. Consequently, the absorption of nutrient ions is reduced due to poor physical state of soil.
- ✓ **Availability of nutrient elements**: The absorption of nutrients depends upon their availability in the soil solution. In case nutrients are available in large quantity in soil solution, the absorption will be more.
- ✓ **Availability of water:** Water acts as a medium for the transportation of nutrients from the soil solution to the plants. If there is less water in the soil, the nutrient ions will move towards roots in small quantity. Hence, there will be less absorption. In an excess of water, there will be less oxygen in soil. It will affect the growth of roots resulting into decrease in the activity of roots.
- ✓ **Temperature**: The absorption of nutrient ions is a bio-process which is affected by temperature. The rate of absorption decreases considerably if the temperature is below 15°C.
- ✓ **Soil pH:** The absorption of nutrient ions depends upon the pH of soil solution. The rate of absorption of nitrate and phosphate ions is high in weakly acidic soils. The absorption of cations is more in neutral and alkaline soils.
- ✓ **Concentration of other ions:** The nutrient ions of similar properties have a competition for absorption in roots. Thus, there is less absorption of potassium in an excess of calcium.

Also, the absorption of zinc is less in an excess of iron. The absorption of zinc and manganese decreases in an excess of phosphorus.

- **Factors related to plants:**
  - ✓ **Nature of root system:** The capacity of plants to absorb nutrient depends on the morphology of root system i.e., the depth and expansion of root system and the number of root hairs. The roots of most plants have depth 0-20cm to absorb nutrients. The depth of crop plants is generally 50–100 cm. The roots of trees are very long.
  - ✓ **Number of ion exchange sites at root surface:** The ion exchange sites in the root surface of dicotyledon plants are more than those of monocotyledon plants. Hence, they have more capacity for ion exchange and these plants absorb calcium comparatively in more quantities. Monocotyledon plants absorb monovalent nutrient element ions more.
  - ✓ **Age and growth rate:** With increasing age, the plant growth decreases and the absorption by roots also decrease regularly.
  - ✓ **Respiration rate:** The plants derive energy in active nutrient absorption by oxidation of carbohydrates in respiration process. Due to low respiration rate, the absorption of nutrients is also low.

Loss of Plant Nutrients from the soil: The plant nutrients are lost from the soil by the following ways:

- By harvested crops.
- By weeds.
- By leaching.
- By erosion.
- Loss in gaseous form.
  - ✓ **By harvested crops:** The nutrient ions are absorbed by the plants from soil solution for their growth. The nutrients are taken away by the harvested crop with it. The loss of nutrients by harvested crops can be reduced by adding FYM and other manures to the soil.
  - ✓ **By Weeds:** The weeds germinate in the fields along with the main crops. These weeds grow fast consuming nutrients from the soil. The weeds should be removed from the fields to avoid loss of nutrients from the soil.
  - ✓ **By leaching:** The water soluble portion of plant nutrients may undergo loss from the soil due to leaching in rain water or irrigation water. The loss of nutrients is more in sandy soils than in heavy soils. Also, the loss of nutrients is more in bare soils than those covered by plants or grass. Nitrogen undergoes maximum loss due to leaching.
  - ✓ **By erosion:** Water and wind cause soil erosion in which top soil is carried away. Due to removal of soil, the plant nutrients present in it are lost.
  - ✓ **Loss n gaseous form**: In this mode of loss of nutrients, nitrogen is lost from the soil in the form of gas. It is due to a chemical transformation in which the soluble form of soil nitroger changes from nitrate (NO3) to elemental nitrogen gas by the activities of soil organisms.

Soil Fertility Evaluation:

Need of Soil Fertility Evaluation:

The main aim of the farmers is to obtain maximum yield of the crop grown in a field. Is possible only when the soil contains all the essential plant nutrients in sufficient quantity in it and the soil conditions are suitable for the proper growth of the crop. Therefore, it is most important to evaluate soil fertility in order to maintain proper physical and chemic conditions of the soil and to grow crops in a scientific manner.

The status of plant nutrients present in a particular soil for the optimum growth of crop and maximum yield is ensured by performing various tests on plants and the soil. This is called **soil fertility evaluation.** This determines the plant nutrient resources of the soil.

The amount of essential plant nutrients in soil is determined under soil fertility evaluation. This tells the requirement of nutrient elements essential for the plants. A result, the fertilizers and soil amendments can be added to the soil in required quantities keeping in view the need of the plants.

Methods for Soil Fertility Evaluation:

Following types of methods are employed for the evaluation of soil fertility:

- Deficiency symptoms of nutrient elements in plants.
- Biological methods.
- Plant analysis.
- Soil analysis.

The main diagnostic methods for soils and crops may be classified as under:

- **Field experiments with fertilizers:** These experiments include :
  - Simple fertilizer trials on cultivator's field.
  - Complex experiments on cultivator's fields and government farms.
- **Pot culture or Greenhouse experiments with fertilizers.**
- **Methods using plants: These methods include**:
  - Visual symptoms or hunger signs of plants.
  - Use of indicator plants.
  - Application of nutrients to leaf surfaces.
  - Nutrient injections for leaf and stem.
  - Foliar diagnosis.
  - Rapid plant tissue tests.
  - Methods using plants as nutrient extractants from soils
    - ✓ **Mitscherlich method**
    - ✓ **Neubaur method**
- **Soil testing methods: These methods include**:
  - Determination of available nutrients by extractant solutions.
  - Determinate ion of exchangeable cations.
  - Soil tests that correlate chemical data with crop response to fertilizer application.
  - Rapid soil tests using soil testing kits.
- **Methods using micro - organisms as extractants:** The methods used to estimate the requirement of nutrients by the soils and crops can be described briefly as follows:

Field experiments with fertilizers: In these experiments, different types of fertilizers are applied in fields in different quantities to a particular crop in order to know the right amount and the right type of fertilizer for various types of soils. This is the oldest method that is being adopted by the various state departments of agriculture. This method is most reliable but it is expensive, laborious and time-consuming.

The field experiments are of two types:

- ✓ **Simple fertilizer trials on cultivator's field:** A large number of trials are conducted on a variety of soil types with different crops. These trials quickly what crop responses can be obtained from fertilizer treatment on soils. Following are the three types of simple fertilizer trials that are conducted on cultivator's fields in different states of India.
- ✓ **8- Plot trials:** In this trial, O, N, P, NP, K, NK, PK, NPK combinations of major nutrients are applied. Here, N represents nitrogen, P phosphorus and K potassium. These trials leading the areas that require application of one or more major nutrients for the increased production of the crop.
- ✓ **7- Plot trials:** In this trial, O, N, N_2, N_1', N_2', N_1'', N_2'', combinations are applied. In this type of trial, three different nitrogenous fertilizers such as ammonium sulphate, urea and calcium ammonium nitrate are compared at two levels of nitrogen. For example: these fertilizers may be applied to wheat corp at 20 and 40 kg of nitrogen per hectare.

The symbols used in this trial are:

- O: Control
- N_1: Ammonium sulphate, $(NH_4)\ 2SO_4$ at 20 kg N/ha
- N_2: Ammonium sulphate, $(NH_4)\ SO_4$ at 40 kg N/ha.
- N_1': Urea, $H_2N.CO.NH_2$ at 20 kg N/ha
- N_2': Urea, $H_2N.CO.NH_2$ at 40 kg N / ha
- N_1'': Calcium ammonium nitrate at 20 kg N/ha.
- N_2'': Calcium ammonium nitrate at 40 kg N/ha.

✓ **5- Plot trials:** These trials are conducted on leguminous crops using O, P_1 ,P_2 ,P_1'. P_2' combines where P_1'', and P_2'', are single and double doses of phosphorus as super phosphate. P_1 and P_2 stand for single and double doses as di-calcium phosphate.

The results of simple fertilizer trials are utilized to work out the recommendations for major field crops.

- **Complex experiments on cultivator's field and government forms**: These experiments require sufficient field and laboratory facilities. Hence, these experiments are conducted on some government farms or on cultivator's field by taking 6 lo 8 hectare of land on lease from the farmers

The field experiments conducted on government farms help us to know the manures and fertilizers to be used along with their quantities for receiving maximum yield of major crops.

Pot culture or Greenhouse experiments with fertilizers:

The representative soil samples are collected from different places in the same field from a plough layer depth of 0-22 cm. These soil samples are mixed thoroughly. About 1 to 4.5kg of this mixed soil is put in different pots or cans of suitable size. Now different fertilizers are applied to each pot leaving aside the no treatment pot. The growth of plants in each case is tested and the effects of fertilizer treatment are compared.

In these pot tests, the plants are grown under uniform conditions and each pot is similar to a plot in the field experiment. These tests are also used to compare plant response to different soils under the same conditions,

Methods using Plants:

❖ **Visual symptoms or hunger signs of plants:** This method is based upon the fact that a plant suffering from some nutrient deficiency or excess of it generally develops a typical sign of disorder mainly in the leaves. The deficiency of plant nutrients causes specific abnormal colors in the leaves. These are called the hunger signs too.

The hunger signs can be easily detected by eyes but it is not easy to know the nutrient in which the soil is deficient. The deficiency symptoms are first developed in the lower or upper parts of the plant.

N, P, Mg, K and Zn are the plant nutrients that show deficiency symptoms on older or lower leaves because these nutrients are highly mobile.

Ca, B. Cu, Mn, S and Fe are the plant nutrients that show deficiency symptoms on younger leaves or bud leaves because these nutrients are less mobile.

Different plant nutrients have specific deficiency symptoms. For example: The deficiency of nitrogen causes yellow or pale green color of leaves, drying up or firing of bottom leaves and short height of the plant. The deficiency of phosphorus develops red and purple colors of leaves. Lower leaves start drying and they develop purple color in veins. It causes slow growth and late maturity. The deficiency of potassium causes deformity in leaves. The bottom leaves are burned on margins and tips.

The hunger signs in plants should be identified carefully before giving fertilizer recommendations because sometimes these symptoms are confusing. For example: Yellowing of leaves is possible not only due to the deficiency of N but also due to Mo or S. The plants also become yellow in water - logging conditions.

Difficulties associated with use of Hunger Signs of Plants.

- Deficiency symptoms become complicated because of the following reasons.
  - **Soil conditions:** It involves water logging and lack of water, lack of organic matter and lack of compactness.
  - **Weather conditions:** It involves wind, drought, low temperature and frost.
  - **Toxic effects of excessive plant nutrients:** Excess of N, P, K, Mg, Cu, Mn and B cause toxic effects.
  - **Attack of pests and insects**: Pests and virus cause diseases in plants.
  - **Mechanical diseases:** These are due to damage from fertilizers and damage from spray.
- Plants / crops develop deficiency symptoms late in the south period. Therefore, it may be late to apply various plant nutrients like P and K to get maximum yield of the crop.
  - **Use of Indicator Plants:** Some plants are specific to particular deficiencies due to different essential plant nutrients. The plants that show special deficiency symptoms are called indicator plants.

    Some indicator plants that are used to know the deficiency of various nutrients are as follows:

Indicator Plants	Deficient Element
Cauliflower, Cabbage, Maize	Nitrogen
Rape (TORIA), Maize, tomato	Phosphorus
Potato, sugarcane, vegetables	Potassium
Potato, beans, cheri	Magnesium
Cauliflower, Cabbage, Barseem	Calcium
Cauliflower, cabbage, oats, potato	Iron
Sugarbeet, oats, potato, lemon	Manganese
Sugarbeet, turnip, carrot, apple	Boron and Sodium
Maize, paddy, tomato, onion	Zinc
Maize, tomato, onion, tobacco	Copper

- **Application of nutrients to leaf surfaces:** The nutrients are applied to leaf surface by spraying or painting.

  The principle of this method is that nutrients are readily absorbed by actively growing leaves. Therefore, the nutrient solutions of suitable concentrations are sprayed on young leaves. The responses to spraying treatments can be visualized in 10 to 40 days after application. Sometimes it may be evident after 5-7 days only.

  Alternatively, the plant nutrient solutions are painted on half the surface of growing leaves. The effect of painting is observed in changing the color of painted portion making it green within a week.

  This method is useful for miconutrient deficiencies where the amount of nutrient needed to cause a response is quite small. The concentration of nutrient solution applied should not be strong otherwise the leaves may be scorched and damaged.
- **Nutrient injections for leaf and stem:** This method is similar to leaf spray in action. In this method, the nutrient solutions or solid salts are injected into the leaves, stems or trunk where they are absorbed and translocated by the growing plants. In order to avoid damage, suitable dose and the time of application must be made by experience. This method is most suitable for micronutrients.
- **Foliar diagnosis**: In this method suitable fertilizer solutions are sprayed on the leaves of the plants. This method is based on analyzing the leaves of high and low yielding plants of the same age for a particular nutrient. The leaves of low - yielding plants grew a lower percentage of nutrients as compared to the leaves of high yielding plants. Low nutrient percentage in plants grown is an area compared to nutrient percentage in high yielding plants show the extent of deficiency of nutrients. N. P and K are the common nutrients tested by this method.
- **Rapid plant tissue tests:** Plant tissue tests are done on plants that are above the ground. The plant tissues accumulate nitrate, phosphate and portions of the growing potassium in the form of inorganic ions which can be identified by chemical tests. Hence, rapid plant tissue tests are also called quick chemical tests.

The percentage of nutrient content in a plant varies with the supply of nutrients available for the growth of the plant. In such tests, the nutrients are extracted from the leaf parts using chemical reagents. The concentration of a nutrient is estimated by difference in the intensity of the color developed in the test. The results are classified as low, medium, high and very high on the basis of intensity of the color. In case, the rapid plant tissue test shows a high value for a nutrient, there is no need to supply that particular nutrient to the crop. If the value is low, the crop lacks the nutrient. Hence, the deficient nutrient should be immediately applied through soil or foliar spray. These tests can be applied at any time during the growing period. These tests provide a reliable basis for the recommendation for fertilizers.

The chemical tests for nitrate, phosphate and potassium on plant tissues can be performed as follows:

- ✓ **Plant tissue test for nitrate:** In most crop plants, nitrogen accumulates as nitrate.
  - ➢ **Diphenylamine test:** This test is applied for determining relative abundance of nitrates in plant tissues.

    In order to perform nitrate test in thin stalk plants such as wheat, barley and bajra, a plant is rooted. Its stem is cut near the lower node at an angle. Add 2-3 drops of diphenylamine solution on it. The development of dark blue color shows that nitrate is in abundance.

    In case of maize, test for nitrate is performed at the base of the leaf midrib without destroying the entire plant. A vertical section is cut at the plant node and 1-2 drops of diphenylamine are added on it. The development of blue color indicates that the plant sap contains nitrogen as nitrate.

    The intensity of blue color denotes the concentration of nitrate nitrogen in the plant sap. On this basis, the recommendation of nitrogenous fertilizers can be made as under:
    - **No color:** It indicates that the plant is severely deficient in N. Hence, there is an urgent need to supply nitrogenous fertilizer.
    - **Slight blue color:** It shows that the plant is slightly deficient in N. There is a need to apply nitrogenous fertilizer.
    - **Medium blue color:** This shows that the plant is only slightly deficient in N. In this case, the application of N fertilizer will result in slight increase in crop yield and it will increase protein in cereals.
    - **Dark blue:** This shows that the plant has sufficient nitrate N. Hence, there is no need to apply nitrogenous fertilizers.
- ✓ **Plant tissue test for phosphate:** The cell sap of the plant contains inorganic phosphate.
  - ➢ **Ammonium molybdate test:** This test is carried out with the leaf tissues. After removing thick midrib, the leaf blades are cut into fine pieces. Take a teaspoon of finely cut tissues in a test tube. Add 4-5 ml ammonium molybdate solution to it and shake the contents vigorously. Now add a little of stannous oxalate to it and mix the contents thoroughly. Observe the color.

The intensity of blue color developed indicates the presence of inorganic phosphate in the plant tissue. On this basis, the recommendation of phosphatic fertilizer can be made as follows:

- **No color or yellow color:** It indicates that the plant is highly deficient in P. Therefore, there is a need to apply phosphatic fertilizer in order to increase crop yield.
- **Green or bluish green:** This shows that the plant is deficient in P. Hence, it needs phosphatic fertilizer.
- **Light blue:** This shows that the plant has medium content of P. The application of phosphatic fertilizer may increase the yield slightly.
- **Medium blue:** It indicates that the plant is supplied with P adequately. Hence, there is no need to apply phosphatic fertilizer.
- **Dark blue:** It indicates that the plant is abundantly supplied with P. Hence, there is no need to apply phosphatic fertilizer. If the phosphatic fertilizer is to be applied, generally superphosphate is applied.

  It contains water soluble P which is utilized by growing plants immediately.

Foliar application of phosphatic fertilizer of suitable concentration is more effective than soil application during growth period. However, soil application of phosphatic fertilizers can be recommended for long duration crops such as sugarcane, tea and coffee.

- ✓ **Plant tissue test for potassium:**

Potassium exists in plant cell sap in soluble form.

- ❖ **Sodium cobaltinitrite test:** The leaf tissues are cut into fine pieces. Take 1/4 teaspoon of the finely cut leaf tissue in a test tube. Add 5 ml of cobaltinitrite solution at 21°C. Shake vigorously for 1 minute and add 5 ml of 95% ethyl alcohol to it at the same temperature and mix. Observe the amount of precipitate formed after 2-3 minutes.

  Note: In potassium determination, the temperature control is very important. Ice - water may be used in order to maintain temperature. The degree of turbidity formed indicates the potassium content in the plant. Thus,
- ❖ **Only a trace of turbidity**: It indicates that the supply of K is deficient and, hence, potassic fertilizer needs to be supplied to the soil as a top dressing or in the form of foliar spray.
- ❖ **Medium turbidity:** It indicates doubtful supply of K.
- ❖ **Very high turbidity:** It shows adequate supply of K. Hence, there is no need to apply potassic fertilizer.
- ❖ Methods using plants as nutrient extractants from soils.

Mitscherlich method

Mitscherlich, a German scientist developed this method. This method is used to study the effect of:

- ✓ Individual plant nutrient such as N, P and K on crop yield in various soils.
- ✓ Increasing doses of individual growth factors such as N on crop yield in various soils.

In this method, oats are grown as test plants in various pots provided with drainage hole. Each pot contains one part soil and two parts sand, for example: about 2.7 kg of soil and 5.4 kg of sand. The fertilizer treatment given involves NPK NP, N K and PK fertilizers. The yield obtained in case of NPK treatment is taken as the maximum i.e. 100%. The other treatments indicate the deficiency of one major plant nutrient as given next:

NPK: Full treatment. It gives 100% yield.
NP: Full treatment minus K
NK: Full treatment minus P
PK: Full treatment minus N

The yield obtained in NP, NK and PK treatments is compared with NPK yield. For the above treatments, the following plant nutrients are added per pot:

- 1: 0g of N as ammonium nitrate in 50 ml of water.
- 1.1g of P2 Os as superphosphate in 50 ml of water.
- 1.5g of K2Oas potassium sulphate in 50 ml of water.

Neubaur method

This method was developed by Neubaur and Schneider in 1923 to determine the deficiency of P and K in soils. In this method, rye seedlings are grown in glass dishes under standard conditions at 20 ° C for 18 days in 100g soil. The amounts of P and K absorbed by seedlings are determined. The values obtained are root soluble quantities in soil. These values are compared with the values obtained from soils giving high yields of crops. The fertilizers are recommended on the basis of the difference of these t vo values. If P is less than 3.5 mg per 100g of soil, it indicates deficiency of phosphorus.

Use of Plant Analysis

The plant analysis is used in the following ways:

- ➢ **Diagnosis:** Plant analysis helps in the diagnosis of visible characteristics. After knowing the symptoms due to deficiency of plant nutrients, the diagnosis is confirmed.

- **Detection of hidden hunger**: Sometimes, the deficiency symptoms of nutrients are not visible inspite of deficiency. This can be known only by plant analysis.
- **Assertaining nutrient availability:** The availability of nutrients and effect of the plant nutrients added on the plant can be verified by plant analysis.
- **Interaction or Antagonism among nutrients**: Plant analysis is helpful in knowing the interaction and opposite effects among the nutrients.
- **Understanding of reactions taking place in plants:** The plant analysis helps to know the mobility of plant nutrients in the plants and other changes that take place in plants.
- **Understanding of Problems related plant growth:** Sometimes the plant growth is not upto the mark even after improving plant nutrient. The observations of plant analysis help to understand the need of soil analysis.

Soil Testing Methods

Soil analysis is defined as the accurate and rapid chemical analysis of soil to determine available nutrient status in the soil. Thus, the basic principle of soil analysis is to determine the plant nutrient resources of a soil by chemical analysis. The available nutrients of a soil are determined in soil testing laboratories.

Following soil analysis methods are carried out in various countries:

- Determination of available nutrients by extractant solutions.
- Determination of exchangeable cations.
- Soil tests that correlate chemical data with crop response to fertilizer application.
- Rapid soil tests with Soil testing kits.

The Purpose (Object) of Soil Testing

The main object of soil testing in India is to get maximum crop yield by applying limited available fertilizers to the soil. Hence, maximum benefit is to be achieved from the fertilizer for food production.

Soil testing is multipurpose. Its main purposes are as under:

- Soil testing helps in estimation of available plant nutrients.
- It helps to group soils into classes related to the levels of nutrients to suggest fertilizer recommendation.
- It helps in predicting the probability to get a profitable response to fertilizer application.
- It helps to evaluate soil productivity.
- It helps to determine soil conditions like acidity, alkalinity and salinity. These soil conditions can limit crop yield. These conditions can be improved by using soil amendments and by suitable management practices.
- It enables to inform the farmers about the nutrient deficiency in a particular soil and to recommend application of suitable fertilizer accordingly.

Soil testing procedure can be divided into the following steps:

(i) Soil sampling.
(ii) Analytic methods involving estimation of available nutrients, lime reqiurement and gypsum requirement.
(iii) Correlation of soil tests with crop response.
(iv) Interpretation of results of soil Testing and recommendations of fertilizers.
(v) Preparation of soil fertility map

Block development officers (BDO) encourages the farmers to send samples of their soils to soil testing laboratories. The soil analysis data and the fertilizer recommendations are conveyed to the farmers in different states.

Advantages of Soil testing to Farmers

Soil tests help the farmers in the following ways:

- To increase net profit: By reducing the total cost of fertilizer without affecting the yield helps to increase net profit.

- To increase yields and net profit: It can be achieved by applying fertilizers within the same total cost but readjusting the proportion of N, P and K on the basis of level of already available nutrients in the soil.
- To adjust fertilizer dose: The recommendation of increased total fertilizers at additional cost is done in such a way that the fertilizer dose will result in much higher yields as well as larger net profit.

Methods using Micro - Organisms as Extractants

Some micro - organisms are used in place of higher plants such as oats and rye in these diagnostic methods. The requirement of mineral nutrients for certain micro-organisms and crop plants are found to be similar in nature. Therefore, micro - organisms such as azotobacter (bacteria) and aspergillus niger (fungus) are used as extractants in these diagnostic techniques. This micro - organisms extract the nutrients with the same power as the field crops. The micro-organisms are used to estimate the deficiency of a particular nutrient or nutrients in a soil sample.

In this method, a known weight of air - dry soil is added to a prepared nutrient solution which lacks only the plant nutrient under test. It is inoculated with spores of the selected micro-organism azotobacter or aspergillus niger. The culture is incubated for a standard period. After this the weight of dried fungus is determined. It is compared with a standard grown with a complete nutrient solution. The difference in weight indicates the status of the nutrient under test. This status is indicated as low, medium or high.

Nutrient Index (NI)

It is also called soil fertility index. On the basis of nutrient index, derived from the result of soil analysis, the soil fertility group can be determined. The nutrient index is calculated with the help of number of samples with low, medium and high categories for each available nutrient element. For this, Parker and other scientists in 1951, used the following formula to calculate NI.

$$NI = \frac{(VL \times 1)+(L \times 2)+(M \times 3)+(H \times 4)}{T}$$

Where NI = Nutrient index.

VL = No. of samples of very low category.

L = No. of samples of low category.

M = No. The soil samples of medium category.

H = No of samples of high category.

T = Total samples is all four categories.

On the basis of NI, the soil of a particular region is categorized as very low, low, medium and high fertility group.

The nutrient indexes for different fertility groups are as follows:

Very low fertility group: 0.0 to 1.75

Low fertility group: 1.76 to 2.5

Medium fertility group: 2.51 to 3.25

High fertility group: Above 3.25

Following table shows the soil fertility groups on the basis of nutrient index of available nutrients:

Soil Groups based on Nutrient Index

Available nutrient	Very low or low category%	Medium category%	High Category%	Nutrient Index
Nitrogen, N	63.0	26.0	11.0	1.48
Phosphorus, P	42.0	38.0	20.0	1.78
Potassium, K	13.0	37.0	50.0	2.37

With the help of statistics regarding soil fertility, the recommendations for fertilizers can be made at the state or higher level. Soil fertility maps can also be prepared on this basis. In this way, N I may help in assuring improved cultivation.

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