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Mineral Nutrition

The absorption, distribution and metabolism of various mineral elements by plants is called mineral nutrition. All organisms need nutrition. Plants have the nutritional requirement of various inorganic and organic raw materials for building their structure and maintaining body functions. Plants generally derive their inorganic nutrients from soil, water and atmosphere.

We know that in plants, nutrition is mainly autotrophic. All plants which possess chlorophyll, synthesize their food with the help of energy of sun-light, H_2O and CO_2. C, H, O and N play a significant role in the constitution of energy rich organic compounds like carbohydrates, lipids and proteins. Over and above these, plants require various essential elements for their survival, growth, proper development and reproduction. These mineral elements occur mainly in their inorganic ionic forms in the soil. Plants absorb them from the soil through their root system.

The study of mineral nutrition is concerned with the absorption of essential mineral nutrients, their important role in the plant life and the effects of their imbalanced availability. If the minerals are not available to plants, specific symptoms appear due to the deficiency of a particular element.

Methods to study the requirement of Mineral in plants

Out of some methods such as Hydroponics, Aeroponics, and Organoponic to determine the requirement of minerals by plants, hydroponic method is described as below.

To understand the role of an individual mineral element and to understand the effects of its deficiency or absence, 'Hydroponic' method of growing plants is employed.

The technique of growing plants only in a nutrient medium and in complete absence of soil is known as Hydroponics. It was demonstrated for the first time by a German Botanist Julius Von Sachs in the year 1980. Minerals are absorbed by plants in solution form. So it is possible to grow plants in water containing the desired amount of mineral salts taking care that the aerial parts are exposed to air and light.

Hydroponics is soil less cultivation of plants. It is a method of growing plants using mineral nutrient solutions instead of soil. That is, soil acts as a reservoir source of nutrients for the plants but the soil itself is not required for their growth. So, the essential nutrients are introduced to the growth

Hydroponic methods

of plants artificially in a water medium. This is the principle of hydroponics. In hydroponics, plants are grown with their roots in the mineral nutrient solution only.

The root system of the plant is maintained in a solution containing various mineral nutrients dissolved in it, instead of in a soil. A large amount of such 'nutrient solution' is utilized. Essential mineral elements are dissolved in their determined amounts. Their concentrations and the pH of the medium are periodically checked and maintained at their proper levels. During growth of plants, gaseous oxygen is continuously bubbled through the solution. By doing so, the roots are constantly made O_2 available to them. Various scientists have proposed different methods of preparing such 'nutrient solutions.'

Now, we should withdraw that essential mineral nutrient, the effect of absence of which, we want to study. We can compare the growth of a plant grown in such a solution to that of the plant grown in the normal solution. Thus, we note the effect of the element which we did not provide.

Types of hydroponics

Two types of hydroponics are solution culture and medium cultures.

Solution culture : In solution culture of hydroponics, just the nutrient solution of essential plant nutrients is used for raising plants. There are three types of solution culture.

(1) **Static solution culture :** This is a method of hydroponics used for raising plants and seedlings in solution-filled containers such as glass jars, buckets, tubs and water tanks.

(2) **Continuous flow solution culture :** This is a method of hydroponics where continuous flow of nutrient-filled solution is automated by using a nutrient film technique or NFT.

(3) **Aeroponics :** This is a method of hydroponics where plants or seedlings are raised in an environment saturated with fine drops (aerosol) of nutrient solution.

Advantages of Hydroponics

- Less use of plant nutrients
- Less use of water
- Less utilization of energy and space
- Elimination of soil-borne diseases
- Complete elimination of weeds
- Balanced plant nutrition

Criteria for Essentiality of Elements

Criteria for the essentiality of elements had been given by Arnon and Stout (1939). Many elements are absorbed by the roots from the soil. To determine which one is an essential element, the following criteria are used.

(1) A plant must be unable to complete its life cycle in the absence of the mineral element.

(2) The function of the element must not be replaceable by another mineral element.

(3) The element must be directly involved in plant metabolism.

These criteria are important guidelines for plant nutrition and it is easy to understand the specific function such as the maintenance of osmotic pressure.

Essential Mineral Elements

The term essential mineral element (or mineral nutrient) was proposed by Arnon and Stout (1939).The nutrients or elements which are essential for the healthy growth of the plant are called **essential nutrients or essential elements.**

You know that 112 elements have been discovered until now. Most of the mineral elements present in soil are absorbed by roots of the plant. All minerals which are absorbed by plants are not essential minerals. Various kinds of mineral elements are considered as essential for the plants.

An essential mineral nutrient is one, in the absence of which the plant can not complete its lifecycle. Its absence cannot be compensated by another element.

According to their quantitative requirements, these are classified as - macronutrients and micronutrients. The concentration of macronutrients in the dry mass of plants is about 1 to 10 mg. per 1 gram. Such a concentration of micronutrients is 0.1 mg or less than that. Micronutrients are also called - Trace elements.

Macronutrients include - Carbon, Hydrogen, Oxygen, Nitrogen, Potassium, Phosphorus, Sulphur, Calcium, and Magnesium.

Micronutrients include - Manganese, Copper, Molybdenum, Boron, Zinc, Iron, Chlorine and Nickel. Sodium, Cobalt, Silicon and Vanadium are also seem to be important 'trace elements'.

Essential plant nutrients: their source, relative amounts, functions and classification:

Element	Chemical symbol	Source	Absorbed form	Major Functions	Relative % in plant
Macronutrients					
Non mineral Elements					
Carbon	(C)	Atmosphere	CO_2	In all organic molecules	-
Oxygen	(O)	Atmosphere	O_2	In most of organic molecules	-
Hydrogen	(H)	Soil	H_2O	In most of organic molecules	-
Nitrogen	(N)	Soil	NH_4^+ and NO_2^-, NO_3^-	In proteins, nucleic acids etc.	100
Mineral Nutrients					
Phosphorus	(P)	Soil	$H_2PO_4^-$	In nucleic acids, ATP, phospholipids etc.	6
Potassium	(K)	Soil	K^+	Enzyme activation, water balance, ion balance	25

Sulphur	(S)	Soil	SO_4^{2-}	In structure of coenzymes, ionic balances.	3
Calcium	(Ca)	Soil	Ca^{2+}	Affects the cytoskeleton, membranes and many enzymes, second messenger	12.5
Magnesium	(Mg)	Soil	Mg^{2+}	In structure of chlorophyll and many enzymes, stabilizes ribosomes	8
Micronutrients					
Iron	(Fe)	Soil	Fe^{3+}	In active site of many redox enzymes and electron carriers, In chlorophyll synthesis	0.2
Chlorine	(Cl)	Soil	Cl^-	In Photosynthesis, ion balance	0.3
Manganese	(Mn)	Soil	Mn^{2+}	Activation of many enzymes	0.1
Boron	(B)	Soil	$H_2BO_3^-$, $H_2BO_3^{2-}$	Carbohydrate transport Cell wall component	0.2
Zinc	(Zn)	Soil	Zn^{2+}	Enzyme activation, auxin synthesis	0.03
Copper	(Cu)	Soil	Cu^{2+}	In active site of many redox-enzymes and electron carriers	0.01
Molybdenum	(Mo)	Soil	MoO_4^{3-}	Various process of nitrogen fixation	0.0001
Nickel	(Ni)	Soil	Ni^{2+}	Required for iron absorption.	
Sodium	(Na)	Soil	Na^+	Involved in osmotic (water movement) and ionic balance in plants.	
Cobalt	(Co)	Soil	Co^{2+}	Required for nitrogen fixation in leguminous plants.	
Silicon	(Si)	Soil	Si^{4+}	As a component of cell walls.	
Vanadium	(V)	Soil	$V^{3+, 4+, 5+}$	Necessary for the activation of nitrogenase in the nitrogen fixing bacteria.	

Role of Macro and Micro nutrients and their deficiency symptoms or effects

The 13 mineral nutrients, which come from the soil, are dissolved in water and absorbed through plant's roots. They are not always enough in the soil for a plant to grow healthy. That is why many farmers and gardeners use fertilizers to add the nutrients to the soil.

The absence or deficiency of any of these essential elements shows deficiency symptoms or effects in plant. The symptoms can be studied by hydroponics. Under natural conditions, these effects or symptoms can be taken as indicators of the mineral deficiencies in the soil.

Carbon, Hydrogen, Oxygen and Nitrogen are Non mineral elements. The mineral nutrients are divided into two groups : macronutrients and micronutrients.

(1) Macronutrients : Macronutrients can be divided into two more groups like : **primary** and **secondary nutrients**.

(a) Primary nutrients : The primary nutrients are nitrogen (N), phosphorus (P), and potassium (K). These are usually not enough in the soil so fertilizer is always needed for the growth of the plants. Plants use these major nutrients in large amounts for their growth and survival .

(b) Secondary nutrients : The secondary nutrients are calcium (Ca), magnesium (Mg), and sulphur (S). These are usually enough in the soil so fertilizer is not always needed.

(2) Micronutrients : The micronutrients are boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), molybdenum (Mo) and zinc (Zn). Micronutrients are those elements which are needed in very small (micro) quantities for plant growth. These elements are sometimes called minor elements or trace elements.

Nitrogen (N) : A very important constituent of amino acids, proteins and nucleic acids. It also occurs in the constitution of many vitamins, hormones and chlorophyll.

Source : It is absorbed as NH_4^+, NO_2^- and NO_3^- from the soil.

Deficiency Symptoms :

Deficiencies can reduce yields, cause Yellowing of leaves. (= chlorosis) and stunted growth.

Causes dormancy of lateral buds, the stem axis turns purple, flowering is delayed and cell division is hindered.

Potassium (K) : It's importance is in maintenance of 'ionic-balance' in cells. It is also essential in maintaining turgidity of cells. It plays an important role in regulation of 'stomatal-pore-size.' It is required in the process of protein synthesis and in the activity of some enzymes.

Source : It is absorbed as 'potassium ion' from the soil solution.

Deficiency Symptoms : Deficiencies result spotted or curled leaves and scorched look to leaves. Other symptoms are blackening of terminal regions of leaves, yellowing of intravenous mesophyll, removal of dominance of apical buds as a result, lateral buds develop, increase in respiratory rate, shortening of internodes, degradation of chloroplasts and reduction in cambial activity.

Phosphorous(P) : Phosphorous is a structural component of plasma membrane. It is essential in the constitution of nucleotides and nucleic acids. It is obligatory in all phosphorylation reactions. It also occurs in the structure of some proteins.

Source : It is absorbed as phosphate ion from the soil.

Deficiency Symptoms : Red or purple blots occur on leaf surfaces, induction of dormancy in seeds, premature fall of leaves and flower buds and fruits occurs.

Calcium (Ca) : It is essential in meristematic tissues and in differentiating tissues. It is required in the synthesis of middle lamella which occurs between cells. It is associated with the formation of the

bipolar spindle during cell division. It plays a role in the regulation of cellular metabolism. It is also required for the activity of some enzymes.

Source : It is absorbed as Ca^{2+} from the soil.

Deficiency Symptoms : Deficiency causes stunting of growth in newly developed branches, flowers and roots. Young root tips, shoot apices and marginal regions of young leaves begin to die.

Magnesium(Mg) : It is obligatory for the activity of enzymes involved in photosynthesis and respiration. It is also a constituent of chlorophyll. It is required for maintenance of ribosomal constitution. It is also essential for synthesis of nucleic acids.

Source : It is absorbed as Mg^{2+} ions from the soil.

Deficiency Symptoms : In deficient plants yellowing of intravenous regions of leaf - mesophyll occurs. Old leaves start to die or purple blots begin to appear on them. Premature leaf fall occurs.

Sulphur (S) : It is a constituent of some amino acids. Sulphur also occurs in constitution of vitamin thiamine and biotin. It is also required in the constitution of many co-enzymes.

Source : It is absorbed as SO_2^{2-} ion from the soil.

Deficiency Symptoms : Deficiency shows light green leaves. Yellowing of leaves and stunted growth like deficiency symptoms resemble those for Nitrogen deficiency.

- Accumulation of purple pigments.

Iron (Fe) : It is required in the constitution of electron transport - system components like cytochromes and ferredoxin. It is also needed for synthesis of chlorophyll.

Source : It is mainly absorbed as Fe^{3+} (ferric ion)

Deficiency Symptoms : Deficiency shows pale color of young leaves followed by yellowing of leaves and large veins.

- It's main effect is completely yellowing of leaves.

Manganese (Mn) : The most significant role of Mn^{2+} is to induce photolysis of water during photosynthesis. O_2 is liberated as an outcome. It is also required for activity of enzymes associated with photosythesis, respiration and nitrogen - fixation.

Source : It is mainly absorbed as Mn^{2+}.

Deficiency Symptoms : Deficiency in young leaves may show-brownish, black, or grayish spots which may appear next to the veins.

Zinc (Zn) : It is essential for the activity of carboxylase type of enzymes. It is also needed in auxin synthesis.

Source : It is absorbed as Zn^{2+}.

Deficiency Symptoms : Deficiency leads to stunted growth and yellowing of mesophyll of leaves.

Copper (Cu) : It is required for the activity of enzymes related to oxidation- reduction reactions.

Source : It is absorbed as Cu^{2+}.

Deficiency Symptoms : Deficiency causes dying of the shoot tips and leaf margin of young leaves and wilting and dropping of leaves. Bark of tree becomes rough and gets split and exudes gum-like secretion.

Boron (B) : It is required for absorption and utilization of calcium. It is essential for germination of pollen grain, cellular differentiation and translocation of sugars.

Source : It is absorbed as Boron ions.

Deficiency Symptoms : Deficiency kills terminal buds leaving a rosette effect on the plant. Leaves are thick brown spoted and fruits, tubers and roots are discolored. Death of root tips and shoot-apices and reduction of fruit size.

- Flowers drop off. • Fruit - size diminishes.

Molybdenum(Mo) : It is a constituent of enzymes associated with various process of nitrogen-fixation.

Source : It is absorbed as Mo^{6+} ion.

Deficiency Symptoms : Deficiency signs are pale green leaves with rolled margins.

- Deficiency of nitrogen leads to stunted growth and yellowing of leaves.

Chlorine (Cl) : It is essential for ionic-balance in cells. It is required in cell division and in splitting of H_2O during photosynthesis.

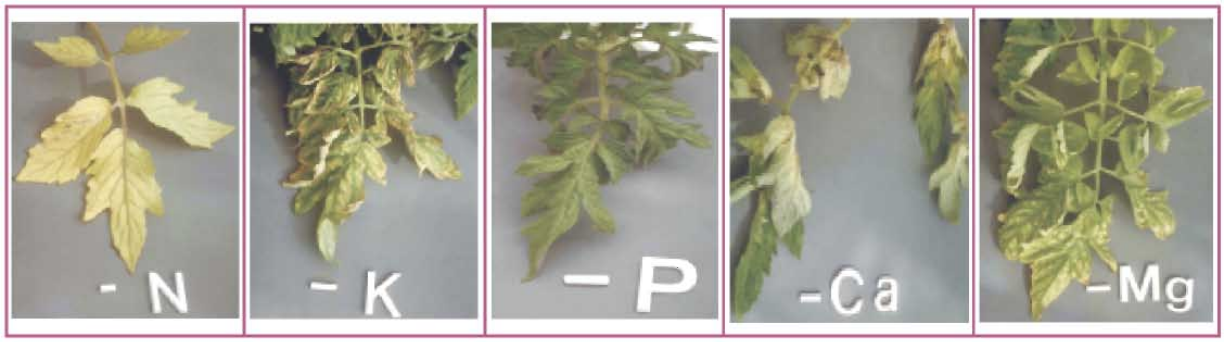
Source : It is absorbed as Cl^-

Deficiency Symptoms : Deficiency symptoms include

- Wilting of stubby roots, yellowing (chlorosis) and bronzing leaves, wilting of leaves.
- Fruit - yield decreases. Growth becomes stunted.

It can be stated that the most common effects of mineral deficiency are -chlorosis of leaves and gradual death of tips and margins of leaves.

Some Minerals Deficiencies



(1) Nitrogen (2) Potassium (3) Phosphorus (4) Calcium (5) Magnesium

(6) Sulphur (7) Iron (8) Manganese (9) Zinc

(10) Copper (11) Boron (12) Molybdenum (13) Chloride

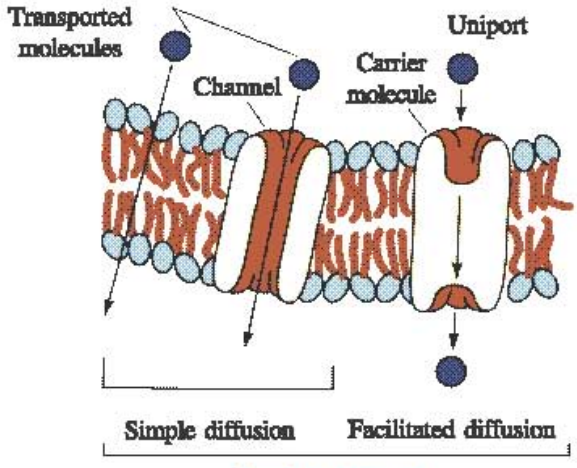
(These diagrams are only for information.)

Toxicity of Micronutrients

The requirement of micronutrients is always low while there moderate decrease causes the deficiency symptoms and a moderate increase causes toxicity. The toxicity symptoms are difficult to identify. Toxicity levels for any element may inhibit the uptake of another element. Manganese inhibits calcium translocation in shoot apex. Therefore, excess of manganese may, in fact, induce deficiencies of iron, magnesium and calcium. Thus, there is no appearing difference between the deficiency symptoms of manganese and deficiency symptoms of iron, magnesium and calcium also.

Absorption of Mineral Nutrients

It seems that there are two main stages in the process of absorption of mineral nutrients from the soil. (1) First of all, the nutrients enter the cell walls of root on the outer side of plasma membrane. Moreover, they also move into the intercellular spaces. This process is relatively more rapid. It occurs through normal diffusion and no energy is expended in it. (2) Then from this extracellular region, the mineral nutrients enter the cellular region. The cellular region means within the plasma membrane and the region within the vacuole. This process occurs in various ways.

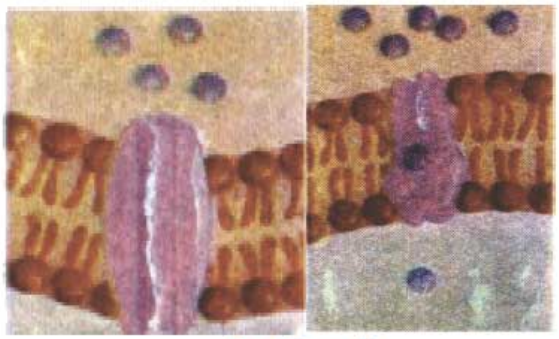


Passive transport

Plants absorb a large number of minerals from soil. The uptake of mineral ions by the roots may be passive or active.

(a) Simple or Passive Absorption : This type of absorption does not require use of any metabolic energy from the cell. It is the initial and rapid phase and ions are absorbed into the "outer space" of the cells. Absorption occurs according to normal physical principles. Examples : The diffusion, Ion Exchange, Donnan Equilibrium, Principle of Mass Flow, osmosis of water, and facilitated diffusion.

Diffusion : A substance moves from where it is in a higher concentration to where it is in a lower concentration. Thus, ions are absorbed following their concentration -gradient. For ionic absorption, various 'ionic - channels' are located in the plasma membrane. Special kinds of proteins which extend along the thickness of the plasma membrane provide pores which act as such 'ion-channels'.



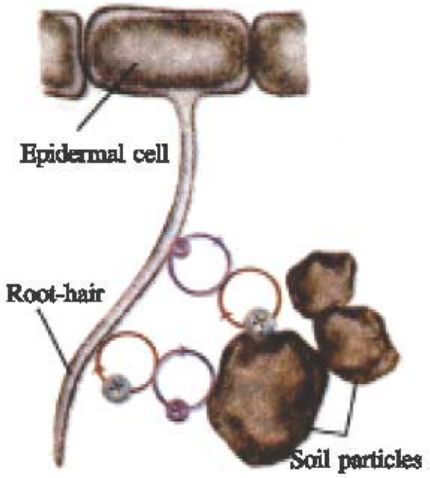
Ion-channels

Ion Exchange : Both, anions and cations are located on the surface of the cell wall through their adsorption. The soil solution also contains ions. An ion exchange occurs between them. Such an ionic-exchange occurs even against their concentration-gradient.

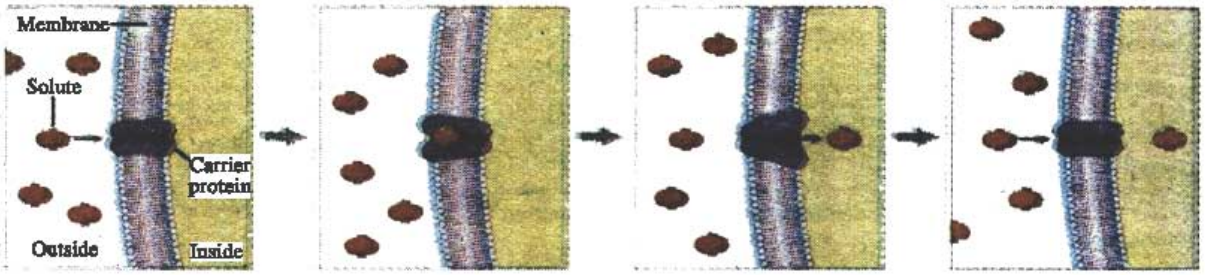
Donnan Equilibrium : Certain ions are incapable of diffusion against their concentration-gradient. The accumulation of such stable and non diffusible ions is explained through this principle. (It occurs against concentration-gradient.)

Plasma membrane possesses selective permeability. It permits exchange of some ions and does not permit that of some others. As a result, there occurs an increase in the concentration of positive ions on the inner surface of plasma membrane. As a result, the inner surface becomes positively charged. Due to this, the negatively charged ions in the soil solution, become accumulated on the outer surface of plasma membrane.

Principle of Mass Flow : According to this principle, large amounts of ions are absorbed along with the absorption of water in large amount. The suction pressure generated by transpiration causing absorption of water is responsible for this. As suction pressure increases, the absorption of water increases and along with water absorption of ions also increases.



Ion Exchange

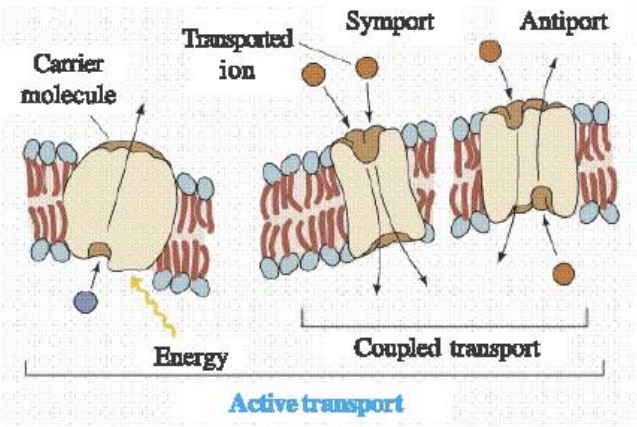


Transport of Ions through Carrier Molecules

(b) Active Absorption : This type of absorption, needs the expenditure of metabolic energy from the cell in the form of ATP. The ions are taken in slowly into the 'inner space'.

Examples : Transport of large molecules, Sodium-Potassium pump.

Such absorption of ions occurs against their concentration ingradient. Energy is consumed in it. Based on a variety of evidences, it seems that specials 'carrier molecules' are involved in this process.



Active transport

These carrier molecules are special kinds of proteins. They combine with ions on the outer side of plasma membrane and form 'ion-carrier complex.' This complex migrates across the membrane towards the inside, where the complex releases the ion. These carrier proteins do not create any pore-like passages.

Translocation of Solutes

Mineral salts are translocated through the xylem vessels to other parts of the plant along with the ascending stream of water by the root system.

The mineral nutrients absorbed by root gradually move across the cortex, endodermis and pericycle towards constituents of xylem. Translocation occurs through apoplast and symplast both. From xylem, their conduction occurs along with the ascent of sap. The rate of transport of water and minerals, also appear to be interrelated.

Soil as a nutrient reservoir

We know that substances can enter plants only in a gaseous or a liquid form. Plants obtain only carbon and oxygen from the atmosphere in the gaseous form as CO_2 and O_2. Except these two, all the minerals are absorbed by plant root system from soil. These minerals are present in soil solution. Even though, nitrogen occurs in a large amount in the atmosphere, it is not available. It occurs as its salts in the soil and is absorbed from there. C, H and O are not considered as mineral elements. Simillarly, N is also not considered a mineral as its original source is air.

All other elements enter the plants from the soil, through their absorption by their root system. These elements occur in solute forms in soil solution.

Nitrogen is absorbed as NH_4^+, NO_2^-, NO_3^-, **Potassium** as 'potassium ion', **Phosphorous** as phosphate ion, **Calcium** as Ca^{2+} ion, **Magnesium** as Mg^{2+} ions, **Sulphur** as SO_4^{2-} ion, **Iron** as Fe^{3+} (ferric ion), **Manganese** as Mn^{2+}, **Zinc** as Zn^{2+}, **Copper** as Cu^{2+}, **Boron** as Boron ions, Molybdenum as molybdenum ions and **Chlorine** as Cl^- ions etc. Macronutrients and micronutrients are absorbed from the soil and soil solution.

Soil contains particles of different sizes e.g. sand (large), silt (medium), clay (small), very small clay particles (colloids) and remain suspended particles in soil solution. Colloids are

(1) mineral (primarily aluminium silicate)

(2) organic (slowly decomposing through weather & microorganisms)

(3) have large surface area

(4) are involved in cation exchange. Therefore, soil acts as a nutrients reservoir.

Nitrogen Metabolism

We learnt earlier that C, H, O and N are amongst the most important essential elements. In living organisms, except C, H and O, N occurs in the largest amount. It occurs in the constitution of important protoplasmic substances like amino acids, proteins, nucleotides, vitamins and hormones.

We also know that the atmosphere contains a large amount of N_2 and that it cannot be directly utilized by any organism. Plants absorb salts of nitrogen like NH_4^+ , NO_2^- and NO_3^- from the soil and incorporate them into their organic constituents. Animals obtain these constituents when they consume these plants as food.

When plants and animals die, their dead bodies are decomposed. During such decomposition which is caused by bacteria, NH_3 is released. This process is called ammonification This NH_3 is immediately converted to NO_2^- and NO_3^- by a process called-nitrification. Specific bacteria are responsible for this. These salts can be absorbed by plants. Some bacteria release N_2 into atmosphere by decomposing nitrates.

Nitrogen cycle

Nitrogen Cycle is an example of gaseous type of biogeochemical cycle. Nitrogen is an essential element of protoplasm, proteins and genetically important nucleic acids such as DNA. It is also a major constituent (about 78%) of the atmosphere. Most green plants need nitrogen in the form of nitrate ions (NO_3^-) and ammonium ions (NH_4^+). Special N_2-fixing bacteria (*Rhizobium*) present in the roots of leguminous plants and certain blue green algae(*Nostoc* and *Anabena*)are capable of fixing nitrogen and converting the same into nitrates(NO_3^-). Lightning also converts gaseous N_2 into nitrates. But the denitrifying bacteria in the soil are transfer the nitrates into gaseous nitrogen and release the same to the atmosphere.

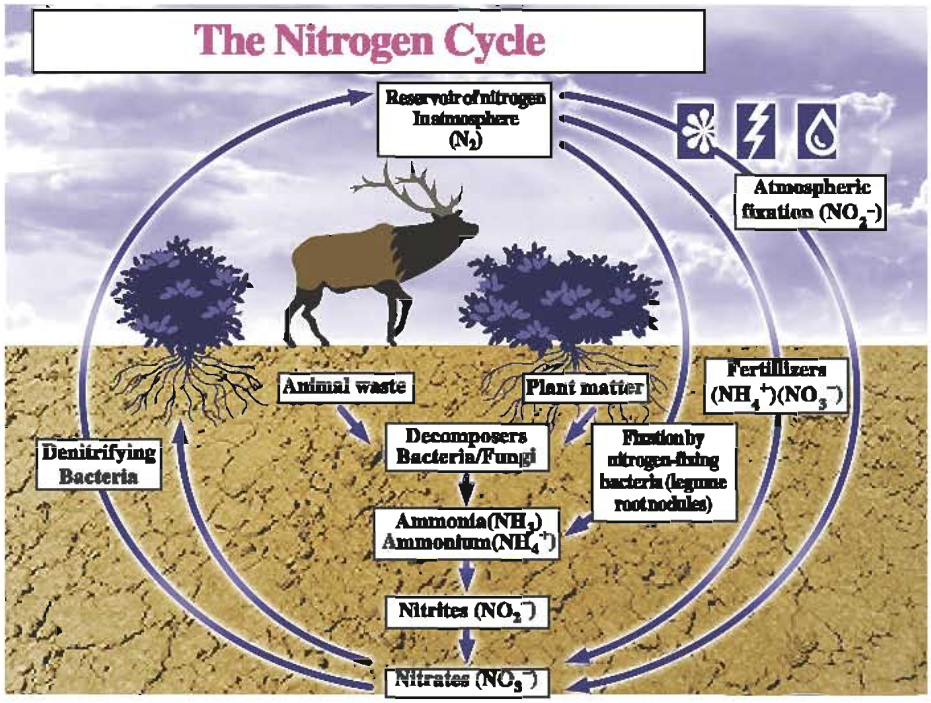
The processes involved in the cycle are fixation, ammonification, nitrification and denitrification.

Ammonification : Ammonification is the transforming process of complex organic matters into the inorganic matters. Dead animals and plant tissues and excretion matters give rise to nitrogenous wastes(complex organic matter). This nitrogenous wastes are converted into ammonia (NH_3) by heterotrophic bacteria, fungi and other decomposers in soil and water. Part of the ammonia is dissolved in water or taken up by plants. It is a one way reaction.

Nitrification : Nitrification is a biological process in which ammonia(NH_3) is converted into nitrite(NO_2^-) and nitrate(NO_3^-). Two types of microorganisms are involved in this process. NH_3 is converted into NO_2^- by *Nitrosomonas* bacteria and then NO_2^- is converted into NO_3^- by *Nitrobacter*. Thus, nitrification is a oxidation process in which nitrogen is increased.

The NO_3^- which is thus formed is once again utilized by green plants for the synthesis of proteins. And gaseous N_2 is converted into NO_3^- by lightning, N_2-fixing bacteria and blue green algae. Thus the N_2 cycle goes on continuously in nature again and again.

Denitrification : Some bacteria are capable of reducing nitrates to gaseous nitrogen, a process called denitrification. NO_3 is reconverted into gaseous N_2 by denitrifying bacteria. (*Agrobacterium* and *Pseudomonas)*. e.g. $2NO_3 \rightarrow 2NO_2 \rightarrow 2NO \rightarrow N_2O \rightarrow N_2$



Nitrogen Fixation

Nitrogen fixation is the conversion process of atmospheric nitrogen to ammonia or nitrate. Ammonia is the product of biological fixation and nitrate is the product of high-energy. In biological fixation molecular nitrogen(N_2) splits into two atoms of free nitrogen:

$$N_2 \rightarrow 2N$$

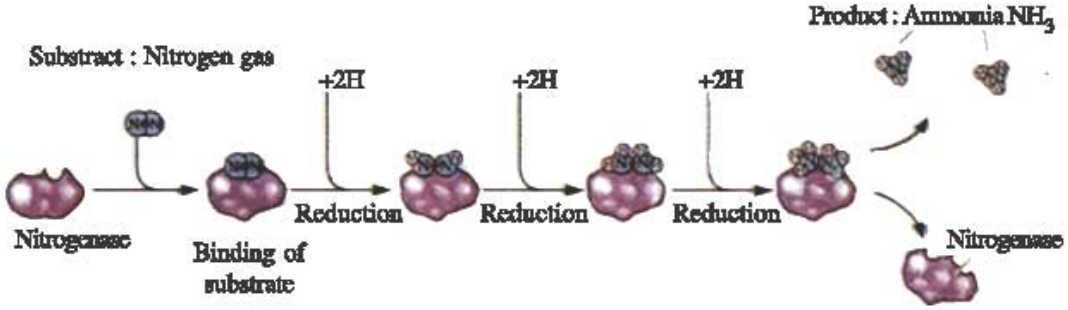
The free nitrogen atoms can combine with hydrogen to form ammonia.

$$2N + 3H_2 \rightarrow 2NH_3$$

This process is mainly carried out by living organisms i.e. specific bacteria and blue-green algae. Therefore it is called biological -nitrogen - fixation.

Symbiotic nitrogen fixation takes place by symbiotic bacteria which are association with roots of leguminous and non-leguminous plants and are known as *Rhizobium*. Non-symbiotic nitrogen fixation takes place by Blue-green algae (*Nostoc* and *Anabena*) and free-living soil bacteria (the aerobic *Azotobacter* species and the anaerobic *Clostridium* species).

Symbiotic nitrogen fixation : This type of biological fixation of nitrogen is accomplished by symbiotic bacteria.



Nitrogen Fixation

Legumes, the most conspicuous of the nitrogen - fixing plants, have a symbiotic relationship with members of the bacterial genus *Rhizobium*. They exist in the immediate surroundings of the plant roots called rhizosphere. There they multiply and increase in size, resulting in swollen infected mass of cells called root nodules, in which an oxygen carrying red pigment hemoprotein, termed as leghemoglobin, similar to hemoglobin of animal blood, is present. A nif-gene (nitrogen-fixation gene) present in *Rhizobium* is responsible for synthesis of nitrogenase enzyme. This enzyme is extremely sensitive to the presence of oxygen. Leghemoglobin accepts oxygen and thus protects the enzyme from its side effects. This process of Biological fixation possess low energy requirement regulated by two enzymes which are nitrogenase (an iron containing protein) and hydrogenase (a molybdenum containing protein).

In nitrogen fixation, nitrogen is reduced through addition of hydrogen. The three bonds (N ≡ N) between two atoms of nitrogen are opened up and three units of H_2 are introduced. In this way two molecules of NH_3 are formed.

Three components are required for this. (1) Reduction inducing unit: FAD(flavin adenine dinucleotide) acts as such a unit. FAD is synthesized during photosynthesis and respiration. (2) Energy as ATP: Energy is provided by ATP in the introduction of H_2 units in a diatomic N_2 unit. (3) Essential Enzymes.

Synthesis of Amino Acids : NH_3 is initially utilized in the synthesis of amino acids. We know that in the structure of an amino acid, there always occurs at least one amino group and one carboxyl group.

There are two main methods of amino-acid synthesis in plants.

(1) Reductive Amination : In this method, α-Keto - glutaric acid reacts with ammonia (NH_3) and forms the amino acid, named glutamic acid. The enzyme glutamate dehydrogenase is responsible for this.

(2) Transamination : In this method, an amino group is separated from one amino acid and it is transferred to a keto group in another keto kind of acid. Glutamic acid acts as a main donor of amino group. Other seventeen kinds of amino acids are synthesized in this way. The enzymes responsible for this are of transaminase types.

Synthesis of Proteins : Various kinds of amino acid units become joined with one another in various numbers and various sequences to form polypeptide chains through peptide bonds. There can be one or more polypeptide chains in the constitution of proteins.

Summary

The absorption, distribution and metabolism of various mineral elements by plants is called mineral nutrition. All organisms need nutrition. We know that in plants, nutrition is autotrophic. Mineral elements occur mainly in their inorganic ionic forms in the soil. Plants absorb them from the soil through their root systems. The study of mineral nutrition is concerned with the absorption of essential mineral nutrients, their important role in the plant life and the effects of their imbalanced availability cause specific symptoms.

Some methods to determine the requirement of minerals by plants are as Hydroponics, Aeroponics, and Organoponic. Criteria for Essentiality of Elements are

(1) A plant must be unable to complete its life cycle in the absence of the mineral element.

(2) The function of the element must not be replaceable by another mineral element.

(3) The element must be directly involved in plant metabolism.

The nutrients or elements which are essential for the healthy growth of the plant are called essential nutrients or essential elements. About 112 elements have been discovered until now. Only twenty kinds of mineral elements are considered as essential for the plants. Most of the mineral elements present in soil are absorbed by roots of the plant. All minerals which are absorbed by plants are not 'essential mineral.' Most of the **mineral nutrients**, which come from the soil, are dissolved in water and absorbed through a plant's roots.

Macronutrients include - Carbon, Hydrogen, Oxygen, Nitrogen, Potassium Phosphorus, Sulphur, Calcium, and Magnesium. Micronutrients include - Manganese, Copper, Molybdenum, Boron, Zinc, Iron, Chlorine and Nickel. Sodium, Cobalt, Silicon and Vanadium are also seem to be important - 'trace elements'. C, H, O and N are Non mineral elements.

The absence or deficiency (not present in the required amount) of any of the essential elements shows to deficiency symptoms or effects in plant. The requirement of micronutrients is always low while there moderate decrease causes the deficiency symptoms and a moderate increases causes toxicity.

Plants absorb a large number of minerals from soil. The uptake of mineral ions by the roots may be passive or active. **(a) Passive Absorption :** This type of absorption, does not require use of any

metabolic energy from the cell. **(b) Active Absorption :** This type of absorption needs the expenditure of metabolic energy from the cell in the form of ATP.

Mineral salts are translocated through the xylem vessels to other parts of the plant along with the ascending stream of water by the root system.

Most of the elements enter the plants from the soil, through their absorption by their root system. These elements occurs in solute form in soil solution. Thus the, soil acts as a nutrient reservoir.

The atmosphere contains a large amount of N_2 and that it cannot be directly utilized by any organism. It occurs in the constitution of important protoplasmic substances like amino acids, proteins, nucleotides, vitamins and hormones. Plants absorb salts of nitrogen like NH_4, NO_2 and NO_3. from the soil and incorporate them into their organic constituents. Animals obtain these constituents when they consume these plants as food.

Nitrogen Cycle is an example of gaseous type of biogeochemical cycle. The processes involved in the cycle are fixation, ammonification, nitrification and denitrification. Ammonification is the transforming process of complex organic matters into the inorganic matters. Nitrification is a biological process in which ammonia(NH_3) is converted into nitrite(NO_2) and nitrate(NO_3). *Nitrosomonas* and *Nitrobacter* are involved in this process. The NO_3 which is thus formed is once again utilized by green plants for the synthesis of proteins. NO_3 is reconverted into gaseous N_2 by *Agrobacterium* and *Pseudomonas* (denitrifying bacteria). This process is called denitrification.

The process of conversion of nitrogen into its salts is called nitrogen fixation. This process is mainly carried out by living organisms. It is called biological -nitrogen - fixation. It is carried out by specific bacteria(*Rhizobium*) and blue-green algae(*Nostoc* and *Anabena*).

In nitrogen fixation, nitrogen is reduced through addition of hydrogen and two molecules of NH_3 are formed. NH_3 is initially utilized in the synthesis of amino acids. Various kinds of amino acid units become joined to form polypeptide chains through peptide bonds and one or more polypeptide chains are presents in the constitution of proteins.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Plants absorbed the mineral nutrients by...

(a) Stem system ○ (b) Root system ○

(c) Leaf system ○ (d) None of these ○

(2) The technique of growing plants only in a nutrient medium in complete absence of soil is known as...

(a) Soil culture ○ (b) Tissue culture ○

(c) Embryo culture ○ (d) Water culture ○

(3) Which is a macronutrient element ?

(a) Manganese ○ (b) Cobalt ○

(c) Phosphorus ○ (d) Sulphur ○

(4) Trace elements is...

(a) Carbon ○ (b) Vanadium ○

(c) Phosphorus ○ (d) Magnesium ○

(5) Non mineral element is...

(a) Nitrogen ○ (b) Molybdenum ○

(c) Nickle ○ (d) Zinc ○

(6) Which element is essential in meristematic tissues and in differentiating tissues?

(a) Phosphorus ○ (b) Cobalt ○

(c) Calcium ○ (d) Nitrogen ○

(7) Yellowing of leaves is known as...

(a) Tylosis ○ (b) Necrosis ○

(c) Florosis ○ (d) Chlorosis ○

(8) Sulphur occurs in constitution of vitamin...

(a) Thiamine ○ (b) Riboflavin ○

(c) Retinol ○ (d) Calciferol ○

(9) Killing of terminal buds leaving a rosette effect on the plant is deficiencies of...

(a) Cobalt ○ (b) Boron

(c) Calcium ○ (d) Phosphorus ○

(10) An example of N_2-fixing bacteria is...

(a) Nitrosomonas ○ (b) Rhizobium ○

(c) Pseudomonas ○ (d) Nitrobacter ○

2. Answer the following questions in short :

(1) Mention the examples of micronutrients.

(2) In which form is nitrogen obtained from the soil ?

(3) Which vessels are involved in mineral salts translocation ?

(4) Give the examples of blue green algae.

(5) What is leghemoglobin ?

3. Define :

Hydroponics, Essential elements, Ammonification, Nitrification

4. Write short notes :

(1) Macronutrients (2) Passive transport (3) Active transport

(4) Nitrogen cycle (5) Diffusion (6) Donnan equilibrium

5. Give the comparative account : Passive transport and Active transport.

6. Answer the following questions in detail :

(1) Give the importance of potassium and its deficiency symptoms.

(2) Mention the toxic effects of nutrients.

(3) Describe the translocation of minerals.

(4) Soil as a reservoir of mineral elements – explain.

(5) Describe the Nitrogen metabolism.

(6) Mention the process of synthesis of Amino acids.