12. Mineral Nutrition

The chemical substance present in food which act as a raw material for body building and maintaining its function are termed as nutrient. Nutrients can be organic or inorganic in nature. Macromolecules such as carbohydrates, fats and proteins are organic in nature whereas CO_2, H_2O and mineral ions are inorganic nutrients.

Plants also require several inorganic nutrients or minerals for their growth, development, structure, physiology and reproduction. The study of source, mode of absorption, distribution and metabolism of various inorganic minerals by the plants is called Mineral nutrients.

1. Methods to Study The Mineral Requirements of Plants (Culture Experiments)

To determine the essential mineral nutrients, the method is plant culture technique. In this technique, plants are grown directly in a soil-free, defined mineral solution. This solution contains all the essential elements in proper proportion that are required for proper growth and development of plants. First, this technique was demonstrated by a prominent German Botanist, Julius Von Sachs in 1860. He grew plants from seeds to maturity in a defined nutrient solution in absence of soil. This soil-less growth of plants in a nutrient solution is known as Hydroponics.

1.1. Hydroponics

In this process, plants are grown in a defined nutrient solution. This nutrient solution is prepared by mixing chemically pure mineral nutrient salts in purified water. The solution is taken in sterilized glass jar or polythene bottles covered with black paper. It minimises the risk of algal contamination and reaction of roots to sunlight. The jars contain split covers or corks with holes for suspending seeding, a funnel for adding solution and a bent tube for aeration. Regular aeration of culture solution is necessary for proper growth and activities of roots. However, the cost of setting up a hydroponics system is very high.

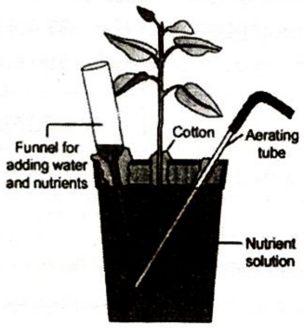


Fig. : Diagram of a typical set-up for nutrient solution culture

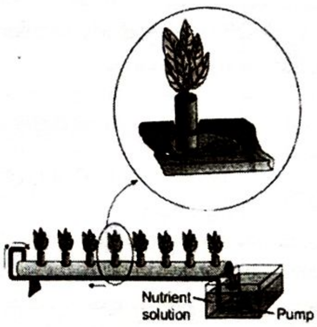


Fig. : Hydroponic plant production

- **Significance**
  - Hydroponics can be employed as a technique for commercial production of vegetables such as tomato, seedless cucumber, lettuce etc.
  - Culture experiments can be used to identify essential elements and their role in structure and function of plants. It can also discover the deficiency symptoms of an essential element. This is done by performing a series of experiments in which the roots of the plants are immersed in nutrient solution and wherein an element is added/removed or given in varied concentration. In this way, we can find the optimum concentration of several mineral elements required by the plant for its proper growth.

2. Essential Mineral Nuritent

Most of the minerals present in the soil can enter through their roots. An elements is said to be essential for plants if it has a specific structural or physiological role and without which plants cannot complete their life cycle. The criteria to know the essentiality of an elements was proposed by Arnon and Stout in 1939.

2.1. Criteria for Essentiality

The criteria to determine the essentiality of an element include the following aspects.

- The element must be absolutely necessary for supporting normal growth and reproduction of plants. In the absence of the element, the plants do not complete their life cycle or set the seeds.
- The element must be directly involved in the metabolism of the plant. It should form a component of either a structural or functional molecule.
- The requirement of the elements must be specific and not replaceable by another element.
- Absence or reduced availability of the element causes disorders.
- The disorders caused by absence or deficiency of an element can be corrected only by the availability of that element.

Based upon the above criteria, 17 elements have been found to be essential for plant growth and metabolism. They are *C, H, O, N, P, K, Ca, Mg, S, Fe, B, Mn, Cu, Zn, Mo, Cl* and *Ni*. Others are called non-essential elements.

2.2. Essential Elements

In 1972, Emanuel Epstein defined two criteria for an element to be essential for plant growth-In its absence the plant is unable to complete a normal life cycle. Or that the element is part of some essential plant constituent or metabolite.

- **Macronutrients :** They are those essential elements which are present in large amounts in plant tissues, *i.e.,* in excess of 10m mole Kg^{-1} of dry matter. Macronutrients are easily detectable because they are present in large quantity. They are usually involved in the synthesis of organic molecules. They are nine in number – carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium and magnesium. Out of these, carbon, hydrogen and oxygen are mainly obtained from CO_2 and H_2O, while the other are absorbed from the soil as mineral nutrients.
- **Micronutrients or trace element :** They are those essential elements which are required by plants in small amounts, less than 10m mole Kg^{-1} of dry matter. Micronutrients are mostly involved in the functioning of enzymes. Since, micronutrients are required in traces, they are also called trace elements. Micronutrients are eight in number – iron, manganese, copper, molybdenum, zinc, boron, chlorine and Nickel.
- **In addition to the 17 essential :** elements named above, there are some beneficial elements such as sodium, silicon, cobalt and selenium. They are required in metabolic activities of higher plants.

Differences between Macronutrients and Micronutrients

	Macronutrients	Micronutrients
1.	These are nutrients present in plants in easily detectable quantities	These elements are present in plants in very small amounts or in traces
2.	The concentration of a macroelement is above 10 mmole Kg^{-1}	The concentration of a microelement is less than 10 mmole Kg^{-1} of dry matter
3.	They build up the plant body and different protoplasmic constituents	They do not have such a role. They are generally required in the functioning of enzymes
4.	They do not become toxic in slight excess	They are toxic in slight excess
5.	They include C, H, O, N, P, K, S, Mg and Ca (9 in number)	They include Fe, Zn, Mn, B, Cu, Mo, Cl and Ni (8 in number)

Essential elements can also be grouped into four broad categories on the basis of their diverse functions. These categories are

- **Structural elements :** carbon, hydrogen, oxygen and nitrogen are components of cellulose and many other biomolecules. Nitrogen is a constituent of all amino acids, proteins, chlorophyll etc
- **Components of energy-related compounds :** Magnesium is a component of chlorophyll, Phosphorus is a component of ATP.
- **Enzyme activators or inhibitors :** Mg^{2+} is an activator for both ribulose bisphosphate carboxylase-oxygenase and phosphoenol pyruvate carboxylase, Zn^{2+} is an activator of alcohol dehydrogenase and Mo is an activator of nitrogenase, Mg^{2+} is involved in photolysis is water .
- **Maintaining osmotic potential :** Most of the osmotic potential of cell sap is due to inorganic salts such as nitrate Cl^-, K^+, sulphate etc.
- Essential elements can also be categorised as mineral and non-mineral elements on the basis of their source.
- **Mineral elements :** Elements obtained from soil or crust of the earth are called mineral element. For example, *P, K, S, Mg, Ca, Fe, Zn, Mn, B, Cu, Mo, Cl* and *N*.
- **Non-mineral elements :** Elements obtained from atmosphere (air) and water are known as non-mineral elements. For example, C, H and O. Carbon is mostly obtained from air as CO_2 Hydrogen is obtained from water. Oxygen is obtained from both air and water.
- **Role of carbon, hydrogen and oxygen :** These three are non-mineral essential elements which are indispensable for plant growth. C, H and O together constitute about 94% of the total dry weight of the plant. They take part in synthesis of cell wall, storage carbohydrates, protoplasmic constituents and other biochemicals. Hydrogen not only takes part in oxidation-reduction reactions, but is also an important cation as well as determinant of *pH*. Deficiency of any of the non-mineral element reduces growth because they are the parts of framework and protoplasmic substances.

2.3. Role of Macro and Micronutrients

- **Nitrogen :** Mainly absorbed as NO_3^- from the soil. It can also be taken up as NO_2^- or NH_4^+. Required by all parts of a plant, particularly the meristematic tissues and the metabolically active cells. Nitrogen is one of the major constituent of proteins, nucleic acids, vitamins and hormones. Being a component of such a large number of biomolecules, nitrogen is essential for all types of metabolic activities, photosynthesis, respiration, cell growth, cell division and reproductive growth.
- **Phosphorus :** Absorbed in the form of phosphate (either as $H_2PO_4^-$ or HPO_4^{2-}) from the soil. Inside the plant, phosphorus is stored in developing fruits, seeds, storage organs and young meristematic tissues. It is a constituent of cell membranes, certain proteins nucleotides, nucleic acids (DNA and RNA), ATP, NADP and nucleoproteins Required for all phosphorylation reactions. ATP contains energy-rich phosphate bonds.

- **Potassium :** Absorbed as K^+. . It is required in more abundant quantities in the meristematic tissues, buds, leaves and root tips. It helps to maintain an anion-cation balance in cells, involved in protein synthesis, helps in opening and closing of stomata. It is responsible for activating several enzymes connected with phosphorylation, photosynthesis, respiration, synthesis of chlorophyll etc. It helps in maintaining turgidity of the cells.
- **Calcium :** Absorbed in the form of calcium ions (Ca^{2+}) from the soil. Calcium is required by meristematic and differentiating tissues. It accumulates in older leaves. It is a required for synthesis of cell wall during cells division, particularly as calcium pectate in the middle lamella, also required during the formation of mitotic spindle and organisation of chromosomes. Involved in the normal functioning of the cell membranes, activates several enzymes like ATPase, phospholipases, α-amylase etc. Plays an important role in regulating metabolic activities.
- **Magnesium :** Absorbed by plants in the form of divalent magnesium ion (Mg^{2+}). .It is required in growing areas of root and stem, seeds, leaves etc. Occurs as magnesium pectate in middle lamella. It is a constituent of the ring structure of chlorophyll. It is required for binding of ribosome subunits during protein synthesis, activates several enzymes involved in photosynthesis and respiration.
- It is involved in the synthesis of *DNA* and *RNA*.
- **Sulphur :** Plants absorb sulphur from the soil in the form of sulphate ions (SO_4^{2-}). . It is required by young leaves and meristems. It is a constituent of two amino acids methionine and cysteine, also used in the synthesis of some vitamins (thymine and biotin), coenzymes-A and ferredoxin; which are involved in various metabolic activities.
- **Iron :** Required in larger amounts in comparison to other micronutrients. Plants obtain iron in the form of ferric ions (Fe^{3+}). Everywhere in the body of plants. It is an important constituent of proteins involved in the transfer of electrons like ferredoxin and cytochromes. It is reversibly oxidised from Fe^{2+} *to* Fe^{3+} during electron transfer in photosynthesis and respiration. It activates catalase and some other enzymes. It is essential for the formation of chlorophyll and other pigments.
- **Manganese :** Absorbed in the form of manganous ions (Mn^{2+}) from the soil. Required by leaves and seeds. It activates several enzymes involved in photosynthesis, respiration and nitrogen metabolism, and plays a major role in the splitting of water to liberate oxygen, during photosynthesis.
- **Zinc :** Plants absorb zinc from soil as Zn^{2+} ions. Everywhere in the body of plants. It activates various enzymes, especially carboxylases. It is also required in the synthesis of auxin.
- **Copper :** Plants absorb copper as cupric ions (Cu^{2+}) from the soil. Everywhere in the body plants. It is essential for the overall metabolism in plants. Like iron, it is associated with certain enzymes involved in redox reactions. It is reversibly oxidised from Cu^+ to $Cu^{2+}[Cu^{2+} \rightleftharpoons Cu^{2+} + e^-]$ during electron transport. Hence, copper is essential for both photosynthesis and respiration.
- **Boron :** It as absorbed as BO_3^{3-} or $B_4O_7^{2-}$. It is required in leaves and seeds. It is required for uptake and utilisation of Ca^{2+}. It is involved in functioning of cell membrane and pollen germination. It helps in translocation (transport) of carbohydrates through phloem and responsible for cell elongation and cell differentiation.
- **Molybdenum :** Plants absorb it from the soil in the form of molybdate ions (MoO_2^{2+}) Everywhere in the body of plants, however, it is more commonly found in roots. It is a component of several enzymes. Including nitrogenase and nitrate reductase, both of which participate in nitrogen metabolism. It is essential for nitrogen-fixation.
- **Chlorine :** Chlorine is absorbed in the form of chloride anion (Cl^-) from the soil. Everywhere in the body of plants. Along with manganese, chlorine is involved in liberation of oxygen during photolysis of water in photosynthesis. Along with Na^+ and K^+, it helps in determining the solute concentration and the anion-cation balance in cells.
- **Nickel :** It is absorbed from the soil as a divalent cation (Ni^{2+}). Required by Leaves and roots. It is a component of two enzymes, urease and hydrogenase. It is involved in the metabolism of urea.

2.4. Deficiency of essential nutrient

Plants require various mineral elements for their normal growth, development and metabolism. They fulfil their mineral requirement usually from the soil. That means all the essential elements must be present in the soil where a plant grows. If a particular element or a group of elements become limited in the soil, plant growth would be retarded. The concentration of the essential element below which plant growth is retarded is termed as critical concentration. The element is said to be deficient when present below the critical concentration.

- **Mobile elements :** Nitrogen, phosphorus, potassium, chlorine, zinc, nickel, molybdenum.
- **Immobile elements :** Calcium, sulphur, iron, boron, copper.
  Since each element has one or more specific structural or functional role in plants, show certain morphological changes in the limitation of any particular element. These externally visible morphological changes which are produced due to absence or deficiency of essential mineral elements, are called deficiency symptoms. They are also called hunger signs. The deficiency symptoms vary from element to element and they disappear when the deficient mineral nutrient is provided to the plant. However, if deprivation continues, it may eventually lead to the death of the plant.
- **Common deficiency symptoms**
  The most common deficiency symptoms observed in plants include chlorosis, necrosis, stunted plant growth, premature fall of leaves and buds, and inhibition of cell division.
  - **Chlorosis :** It is the loss of chlorophyll leading to yellowing in leaves. It is caused by the deficiency of elements *N, K, Mg, S, Fe, Mn, Zn* and *Mo*.
  - **Necrosis** : It refers to the death of tissue, particularly leaf tissue. It is caused due to the deficiency of *Ca, Mg, Cu, K*.

- **Inhibition of cell division :** It is caused due to lack or low level of *N, K, S* and *Mo*.
- **Late flowering :** Some elements like *N, S, Mo* delay flowering if their concentration in plants is low.

The parts of the plants showing the deficiency symptoms also depend on the mobility of the element in the plant. For elements that are actively mobilised within the plants and exported to young developing tissues, the deficiency symptoms tend to appear first in the older tissues for example, the deficiency symptoms of *N, K* and *Mg* are visible first in the senescent (older) leaves. In the older leaves, biomolecules containing those elements are broken, down, thereby making these elements available for mobilizing to younger leaves.

On the other hand, when the elements are immobile and are not transported out of the mature organs, the deficiency symptoms tend to appear first in the young tissues. For example, elements like sulphur and calcium are a part of the structural component of the cell and hence are not easily released. Thus, the study of mineral nutrition of plants is of a great significance and importance to agriculture and horticulture.

2.5. Toxicity of micronutrients

Micronutrients are always required in low amounts. Their moderate decrease in the soil causes deficiency symptoms. However, a moderate increase in their concentration can cause toxicity as there is a narrow range of concentration at which the elements are optimum. Any mineral ion concentration in tissues that reduces the dry weight of tissues by about ten percent is considered to be toxic concentration. Toxic effects may be due to direct excess of the micronutrient or its interference in the absorption and functioning of other nutrients. For example, the prominent symptom of manganese (Mn) toxicity is the appearance of brown spots surrounded by chlorotic veins. Excess of Mn causes.

(a) Reduction in uptake of Mg and Fe.

(b) Prevention of binding of Mg with enzymes.

(c) Inhibition of Ca translocation of shoot apex. Therefore, excess of manganese may, in fact, induce deficiencies of iron, magnesium.

3. Mechanism of Absorption of Elements

Plants absorb the essential mineral nutrients from the soil through their roots. The most active areas of the root for mineral absorption are the zones of elongation and root hair. The rate of mineral absorption is usually independent of their concentration in the soil. The minerals are absorbed as ions.

The mechanism of absorption of elements by the plants has been studied by placing the isolated plant cells, tissues or organs in a specific mineral solution. these studies revealed that the process of mineral absorption can be demarcated into two main phases – initial and metabolic. These phases are discussed below :

3.1. Initial phase

There is a rapid uptake of ions into the outer or free space of the cells (i.e., the area of apoplast). Outer or free space comprises intercellular spaces and cell walls. In this phase, the ions are absorbed passively, i.e., no energy expenditure occurs. The passive movement of ions into the apoplast usually occurs through ion channels.

3.2. Metabolic phase

In the metabolic phase, the ions pass into inner space (i.e., the symplast area of the cells). The inner space comprises cytoplasm and vacuole. In this phase, the movement of ions is an active process, i.e., the entry of exit of ions to and from the inner space requires the expenditure of metabolic energy. The movement of ions is usually called flux. The inward movement into the cells is influx and the outward movement is called efflux.

4. Translocation of Solutes

It has been proved that xylem is the path of translocation of minerals. Mineral salts are transported through xylem along with the ascending stream of water. This sap is pulled up through the plant by transpirational pull. Analysis of xylem sap shows the presence of mineral salts in it. it has also been proved by the use of radioisotopes of mineral elements that they are transported through the xylem.

5. Soil as Reservoir of Essential Elements

Soil is reservoir of all mineral elements that are essential for the proper growth and development of plants. It consists of a wide variety of substances. Physical processes such as weathering and breakdown of rocks lead to enrichment of soil with dissolved ions and inorganic salts. Since the latter are derived from the rock minerals, their role in plant nutrition is referred to as mineral nutrition. Apart from supplying minerals to the roots of plants, soil plays many other important roles such as :

(1) Soil harbours as large number of microorganisms that not only decompose organic remains but also release the minerals bound in organic matter.

(2) It also harbours nitrogen-fixing bacteria which increase the usable nitrogen content of soil.

(3) Soil holds water and supplies air to the roots.

(4) It acts as a matrix that stabilizes the plant.

However, in agriculture, there is more withdrawal of mineral nutrients from the soil than their natural replenishment. Therefore, there is often deficiency of essential minerals which affects the crop yield. Artificial fertilizers are added to remove the same. Both macronutrients and micronutrients form components of fertilisers and are applied as per need.

6. Metabolism of Nitrogen

Apart from carbon, hydrogen and oxygen, nitrogen is the most prevalent element in living organisms. Nitrogen is a constituent of amino acids, proteins, hormones, chlorophylls and many of the vitamins. However, its availability from the soil is limited, and therefore, plants have to compete with microbes for available nitrogen. Thus, nitrogen is a limiting nutrient for both natural and agricultural ecosystems.

6.1. Nitrogen Cycle

Nitrogen exists as two nitrogen atoms joined by a very strong triple covalent bond $(N \equiv N)$ in the atmosphere. Although, nitrogen is available in abundance (78%) but plants cannot directly absorb the same. Therefore, nitrogen is the most critical element. A regular supply of nitrogen to the plants is maintained through nitrogen cycle.

Nitrogen cycle refers to the regular circulation of nitrogen amongst the various components of the environment, viz. the living organisms, reservoir pool in the atmosphere and cycling pool in the lithosphere (soil). A brief account of the nitrogen cycle is discussed below :

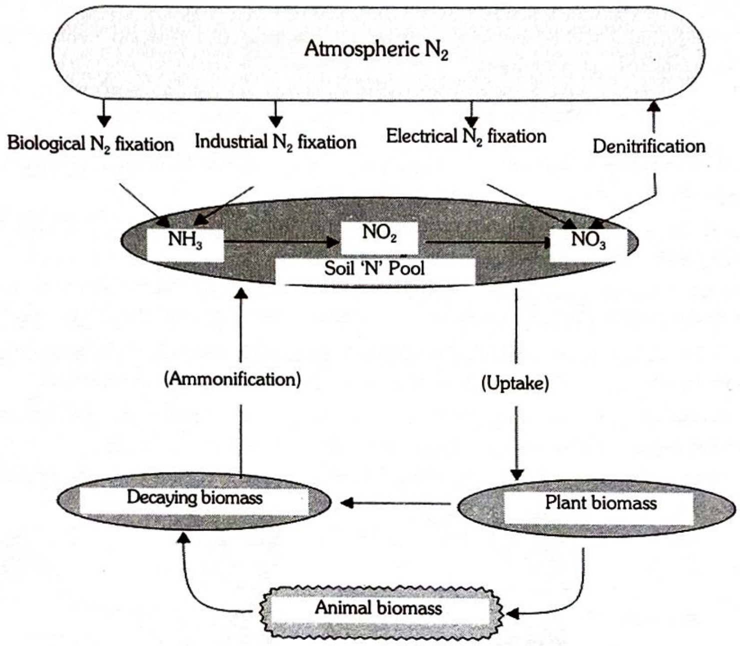


Fig. : The nitrogen cycle showing relationship between the three main nitrogen pools-atmosphere, soil and biomass

- **Nitrogen-fixation :** The process of conversion of atmospheric nitrogen (N_2) to ammonia is called nitrogen-fixation.
  Nitrogen-fixation can occur in the following ways :
  (a) Atmospheric nitrogen-fixation : In nature, lighting and ultraviolet radiations provide enough energy to allow nitrogen to combine with oxygen in order to form nitrogen oxides (NO, NO_2, N_2O).
  (b) Industrial nitrogen-fixation : Industrial combustions, automobile exhausts and power generating stations are also sources of atmospheric nitrogen oxides.
  (c) Biological nitrogen-fixation : Reduction of inert atmospheric nitrogen to ammonia by living organisms is called biological nitrogen-fixation. Only certain prokaryotic organisms (some bacteria and cyanobacteria/blue-green algae) are capable of fixing N_2. Such microbes are called N_2-fixers. These N_2- fixing microbes contain an exclusive enzyme, nitrogenase that is capable of reducing nitrogen.

$$N_2 \xrightarrow[N_2-\text{fixers}]{\text{Nitrogenase}} NH_3$$

  The nitrogen-fixing microbes could be free-living or symbiotic in nature.
  (a) Examples of free-living N_2-fixing bacteria are *Azobacter* and *Beijernickia* (both aerobic). *Bacillus, Clostridium, Rhodospirillum* are anaerobic, free-living, N_2-fixing bacteria.
  (b) Examples of free-living nitrogen fixing cyanobacteria are *Anabaena an Nostoc*.
  (c) Examples of symbiotic nitrogen fixing bacteria are *Rhizobium* and *Frankia*.
- **Ammonification :** Decomposition of organic nitrogen (proteins, nitrogenous excretions etc.) of dead plants and animals into ammonia is called ammonification. It is carried out by decay causing organisms such as *Bacillus ramosus, B. vulgaris, Actinomyces* etc.Proteins are first broken up into amino acids. The latter are deaminated to release organic acids which are then used by the microbes for their own metabolism.
- **Nitrification :** Some of the ammonia released in previous step, volatilises and re-enters the atmosphere but most of it is converted into nitrate by the soil microbes. This phenomenon of conversion of ammonia to nitrate is called nitrification. It is performed in two steps :

(1) In the first step, ammonia is oxidised to nitrites by the action of Nitrosomonas and/or Nitrococcus bacteria.

$$2NH_3 + 3O_2 \xrightarrow[\text{Nitrococcus}]{\text{Nitrosomonas /}} 2NO_2^- + 2H^+ + 2H_2O + \text{Energy}$$

(2) In the second step, nitrite is further oxidised to nitrate with the help of nitrobacter and/or nitrocystis.

$$2NO_2^- + O_2 \xrightarrow[\text{Nitrocystis}]{\text{Nitrobacter /}} 2NO_3^- + \text{Energy}$$

These nitrifying bacteria (*Nitrosomonas, Nitrobacter* etc.) are chemoautotrophs. They use the energy liberated during nitrification in synthesis of organic substances from CO_2 and a hydrogen donor. They are thus autotrophs which do not use solar energy for synthesis of food.

The nitrate thus formed is absorbed by plants and is transported to the leaves. In leaves, it is reduced to form ammonia that finally forms the amine group of amino acids.

- **Denitrification** : Some of the nitrates present in the soil is reduced to gaseous nitrogen by the action of microorganisms. This process is called denitrification. Denitrification is carried by bacteria *Pseudomonas denitrificans* and *Thiobacillus denitrificans.* The released N_2 escapes into the atmosphere.

$$2NO_3^- \longrightarrow 2NO_2^- \longrightarrow 2NO \longrightarrow N_2O \longrightarrow N_2 \uparrow$$

- **Symbiotic Biological Nitrogen-Fixation :** Several types of symbiotic biological nitrogen-fixing associations are known. The most prominent amongst them is the legume-bacteria relationship.

  Species of rod-shaped *Rhizobium* live symbiotically within the roots of several leguminous plants such as alfalfa, sweet clover, sweet pea, lentils, garden pea, broad bean, clover bean, etc. These bacteria produce small outgrowths (spherical) on the surface of legume roots, called as nodules. A microbe, Frankia, also produces nitrogen-fixing nodules on the roots of non-leguminous plants (e.g., Alnus). Both *Rhizobium* and *Frankia* are free living in the soil, but as symbionts, can fix atmospheric nitrogen.

- **Nodule formation :** Formation of root nodules involves a sequence of multiple interactions between *Rhizobium* and roots of the host plant. Principal stages involved in the formation of nodules are summarised below :

  (a) *Rhizobium* multiply and colonise the surroundings of roots and get attached to epidermal and root hair cells. This occurs because legume roots secrete some specific chemicals which attract the bacteria.

  (b) Bacteria collect over the root hairs, release Nod factors that cause curling of root hairs and the multiplication of bacteria.

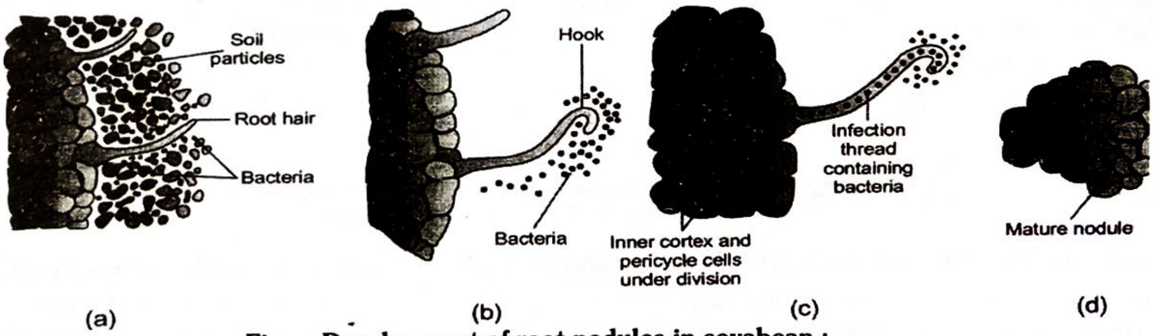


Fig . : Development of root nodules in soyabean :

(a) Rhizobium bacteria contact a susceptible root hair, divide near it,

(b) Upon successful infection of the root hair cause it to curl,

(c) Infected thread carries the bacteria to the inner cortex. The bacteria get modified into rod-shaped bacteroids and cause inner cortical and pericycle cells to divide. Division and growth of cortical and pericycle cells lead to nodule formation,

(d) A mature nodule is complete with vascular tissues continuous with those of the root

  (c) Infected thread carriers the bacteria to the inner cortex where they initiate the nodule formation.

  (d) The invading bacteria stop dividing and get modified into rod-shaped structures called bacteroids.

  (e) Also, the bacteria release signals that cause inner cortical and pericycle cells to divide.

  (f) Division and growth to cortical and pericycle cells lead to nodule formation. The nodule thus formed, establishes a direct vascular connection with the host for exchange of nutrients.

  The nodule, contains all the biochemical components required for N_2-fixation including the enzyme nitrogenase and a red or pink-coloured pigment called leguminous haemoglobin or leg-haemoglobin (LHb).

- **Mechanism of nitrogen fixation :** The enzyme, nitrogenase is required to fix atmospheric nitrogen $(N \equiv N)$. It is made up of Mo-Fe protein and catalyses the conversion of atmospheric nitrogen to ammonia. The molecule of nitrogen is reduced by the addition of hydrogen atoms provided by a reducing agents like $NADPH_2$. It produces dimide (N_2H_2), hydrazine (N_2H_4) and finally ammonia $(2NH_3)$ is formed. The synthesis of ammonia requires very high input of energy (8 ATP for each NH_3 produced). The energy required is obtained from the reaction involved in N_2-fixation is

$$N_2 + 8e^- + 8H^+ + 16ATP \longrightarrow 2NH_3 + 2H^+ + 16ADP + 16P_i$$

Thus, one molecule of nitrogen is converted into two molecules of ammonia.

An important point to note is that the enzyme nitrogenase is highly sensitive to molecular oxygen as it functions under anaerobic conditions.

Thus, the root nodules have adapted themselves that ensure that the enzyme is protected from oxygen. In order to protect these enzymes, the nodule contains a red or pink-coloured pigment called leghaemoglobin. It is O_2 scavenger. The presence of this coloured pigment in the cytosol of nodule cells imparts red or pink colour to the central portion of nodules.

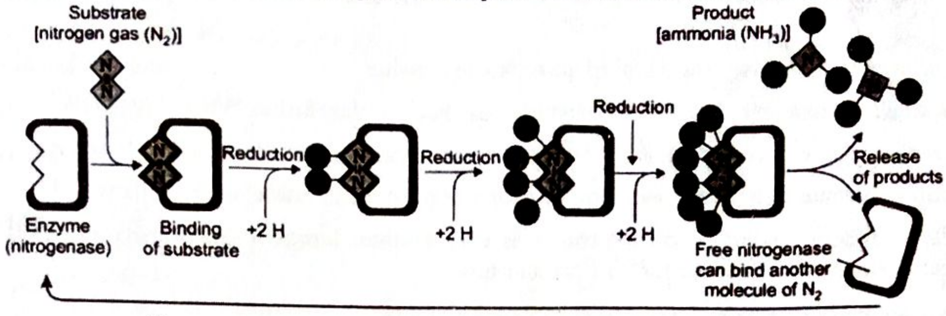


Fig. : Steps of conversion of atmospheric nitrogen to ammonia by nitrogenase enzyme complex found in nitrogen-fixing bacteria

Important -

(1) Legume-Rhizobium association can annually fix 25-60 kg of nitrogen per hectare.

(2) Rhizobium and Frankia live as aerobes under free-living conditions in the soil. However, during nitrogen-fixing events they become anaerobic in order to make the nitrogenase enzyme functional.

(3) Uprooted common pulse plant just before flowering, shows spherical outgrowths on the roots. These are the nodules.

- **Fate of ammonia :** Ammonia, the product of nitrogen-fixation, does not remain in the gaseous form in the soil. It is protonated to form NH_4^+ (ammonium) ion.

$$NH_3 + H^+ \longrightarrow NH_4^+$$

While most of the plants can assimilate nitrate as well as ammonium ions, the latter is quite toxic to plants and hence cannot accumulate in them. Therefore, NH_4^+ is assimilated as soon as it is formed. There are two main ways by which NH_4^+ is assimilated to form amino acids in plants.

(a) Reductive amination : In the presence of enzyme glutamate dehydrogenase, ammonium ion directly combines with α-Ketoglutaric acid, to form glutamic acid. A reduced coenzyme (NADPH) is required.

$$\alpha\text{-Ketoglutaric acid} + NH_4^+ + NADPH \xrightarrow[\text{Dehydrogenase}]{\text{Glutamate}} \text{Glutamate} + H_2O + NADP$$

(b) Transamination : It involves the transfer of amino group ($CHHN_2$) of one amino acid to the keto group ($C=O$) of keto acid. The enzyme required is transaminase or aminotransferase. Glutamic acid is the primary amino acid from which the transfer of amino a group ($-NH_2$) takes place and other amino acids are formed through transamination.

$$\underset{\text{Amino donor}}{R_1-\overset{\overset{H}{|}}{\underset{\underset{NH_3^+}{|}}{C}}-COO^-} + \underset{\text{Amino acceptor}}{R_2-\underset{\underset{O}{||}}{C}-COO^-} \rightleftharpoons R_1-\underset{\underset{O}{||}}{C}-COO^- + R_2-\overset{\overset{H}{|}}{\underset{\underset{NH_3^+}{|}}{C}}-COO^-$$

Example : Glutamic acid + Oxaloacetic acid $\xrightarrow[\text{Aminotransferase}]{\text{Glutamate asparate}}$ α-ketoglutaric acid + Aspartic acid

Important -

Amides : They are organic compounds derived from amino acids in which hydroxyl component ($-OH$) of carboxylic group ($-COOH$) is replaced by another amino group ($-NH_2$). As a result, amides have two amino groups. The two most important amides are asparagines and glutamine. They are formed by amination of glutamic acid and aspartic acid respectively. Glutamine and asparagines are a structural part of proteins alongwith amino acids. These amides perform two other functions – storage of excess nitrogen. Since amides contain more nitrogen than the amino acids, they are transported to other parts of the plant via xylem vessels.

Etiolation : It is a condition, caused by the growth of plant in the absence of light. It is characterised by a pale yellow colouring, sparse leaves and weak, elongated stems. The stems of a plant are grown in order to reach a potential light source.

Zinc has its role in tryptophan synthesis and its deficiency produces leaf malformation or little leaf.

Nitrogen Fixation by Some Microbes

Bacteria	Body organisation	Nutrition	N_2 fixation	Plant association
Rhizobium	Unicellular	Heterotrophy	Symbiotic	Legumes
Frankia	Filamentous	Heterotrophy	Symbiotic	Non-legumes
Anabaena	Filamentous	Autotroph	Symbiotic + free living	Non-legumes
Azotobacter	Unicellular	Heterotrophy	Free living	Not associated

7. Application of Fertilizers

A fertilizer is any material of natural or synthetic origin that is applied to soils or to plant tissues to supply one or more plant nutrients essential to the growth of plants. Fertilizers enhance the growth of plants. This goal is met in two ways, the traditional one being additives that provide nutrients. The second mode by which some fertilizers act to enhance the effectiveness of the soil by modifying its water retention and aeration.

Fertilizers are classified in several ways. They are classified according to whether

- They provide a single nutrient (e.g., *K*, *P*, or *N*), in which case they are classified as "straight fertilizers."
- "Multinutrient fertilizers" (or "complex fertilizers") provide two or more nutrients, for example *N* and *P*.

  Fertilizers are also sometimes classified as inorganic (the topic of most of this article) versus organic.
- Inorganic fertilizers exclude carbon-containing materials except ureas. Inorganic are sometimes called synthetic fertilizers since various chemical treatments are required for their manufacture.
- Organic fertilizers are usually (recycled) plant- or animal-derived matter.

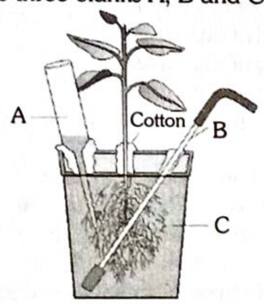
7.1. Some commonly used fertilizers

- The main nitrogen-based straight fertilizer is ammonia or its solutions.
- Ammonium nitrate (NH_4NO_3) is also widely used.
- Urea is another popular source of nitrogen, having the advantage that it is solid and non-explosive, unlike ammonia and ammonium nitrate,respectively.
- A few percent of the nitrogen fertilizer market (4% in 2007) has been met by calcium ammonium nitrate ($Ca(NO_3)2 \cdot NH_4NO_3 \cdot 10H_2O$).
- The main straight phosphate fertilizers are the superphosphates. "Single superphosphate" (SSP) consists of 14–18% P_2O_5, again in the form of $Ca(H_2PO_4)_2$, but also phosphogypsum ($CaSO_4 \cdot 2H_2O$).
- Triple superphosphate (TSP) typically consists of 44-48% of P_2O_5 and no gypsum.
- A mixture of single superphosphate and triple superphosphate is called double superphosphate. More than 90% of a typical superphosphate fertilizer is water-soluble.

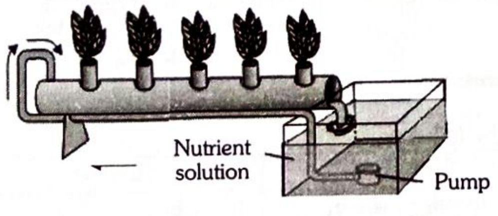
12. Mineral Nutrition – Multiple Choice Questions

1. General

1. Which of the following ions of heavy metals participate in process of photosynthesis in higher plants
(a) *Pb, Fe, Ni, Co* (b) *Mg, Zn, Cu, Hg*
(c) *Mg, Mn, Co, Fe* (d) *Mg, Cu, Mn, Fe*
2. Inorganic nutrients are present in the soil in the form of
(a) Molecules (b) Atoms
(c) Electrically charged ions (d) Parasite
3. In hydrophytic plants, water and salts are absorbed by
(a) Roots (b) Leaves
(c) Stem (d) Outer layer of plants
4. The given figure shows a typical setup for a hydroponic technique. Choose the option which gives a correct set of words for all the three blanks A, B and C



(a) A - Funnel for adding water and nutrients, B - Aerating tube, C - Water
(b) A - Funnel for adding nutrients only, B - Aerating tube, C - Nutrient solution
(c) A - Funnel for adding water only, B - Aerating tube, C - Nutrient solution
(d) A - Funnel for adding water and nutrients, B - Aerating tube, C - Nutrient solution
5. The technique of growing plants without soil in nutrient solutions is called
(a) Parthenogenesis (b) Hydroponics
(c) Aquaculture (d) Tissue culture
6. The given figure shows hydrophonic / soil-less plant production. Plants are grown in a tube or through placed on a slight incline. The arrows indicate the direction of flow of nutrient solution.
Nutrient solution is sent to the elevated end of the tube from the reservoir by ________ and it flows back into reservoir due to ________



(a) Pump, Gravity (b) Gravity, Pump
(c) Gravity, Gravity (d) Pump, Pump
7. Which one of the following statements can best explain the term critical concentration of an essential element
(a) Essential element concentration below which plant growth is retarded
(b) Essential element concentration below which plant growth becomes stunted
(c) Essential element concentration below which plant remains in the vegetative phase
(d) None of the above
8. Plants can be grown in (Tick the incorrect option)
(a) Soil with essential nutrients
(b) Water with essential nutrients
(c) Either water or soil with essential nutrients
(d) Water or soil without essential nutrients
9. It is possible to determine whether an element is essential by observing the growth of plants
(a) On soil from which the particular element is removed
(b) On soil in which only the particular element is present
(c) On an inert medium to which solution of only the particular element is added
(d) On an inert medium to which a nutrient solution excluding that particular element, is added
10. The charcoal culture experiment is better than a water culture experiment because
(a) Plants get support
(b) The problem of aeration is removed
(c) Charcoal is an inert substance
(d) All the above
11. Which one of the following roles is not characteristic of an essential element
(a) Being a component of biomolecules
(b) Changing the chemistry of soil
(c) Being a structural component of energy-related chemical compounds
(d) Activation or inhibition of enzymes

2. Macro-Nutrients

1. Interveinal chlorosis of leaves is caused by the deficiency of
(a) Nitrogen (b) Calcium
(c) Potassium (d) Magnesium
2. Which element is required for the germination of the pollen grain
(a) Boron (b) Calcium
(c) Chlorine (d) Potassium
3. Which of the following does NPK (Critical element) denote
(a) Nitrogen, potassium, kinetin
(b) Nitrogen, protein, kinetin
(c) Nitrogen, protein, potassium
(d) Nitrogen, phosphorus, potassium
4. Necrosis, or death of tissue particularly leaf tissue, is due to the deficiency of
(a) *N, K, S* (b) *N, K, Mg,* and *Fe*
(c) Mn, *Zn* and *Mo* (d) *Ca, Mg, Cu* and *K*
(e) *N, K, Mg, Fe, Mn, Zn,* and *Mo*
5. *K, N, Ca, Mg* deficiency causes
(a) Chlorosis (b) Leaf curl
(c) Exanthema (d) Little leaf
6. Which of the following is not absorbed through the soil
(a) Carbon (b) Nitrogen
(c) Potassium (d) All the above
7. Which of the following element is used up in phosphorylation
(a) Calcium and sulfur
(b) Chlorine and manganese
(c) Iron and phosphorous
(d) Magnesium and phosphate
8. Those fertilizers, which provide all the essential elements such as *N,P* and *K etc.* required for plant growth, are called
(a) Direct fertilizers (b) Indirect fertilizers
(c) Complete fertilizers (d) Incomplete fertilizers

9. Which is essential for root hair growth
(a) *Zn* (b) *Ca*
(c) *Mo* (d) *S*

10. The major role of phosphorus in plant metabolism is
(a) To generate metabolic energy
(b) To evolve oxygen during photosynthesis
(c) To evolve carbon dioxide during respiration
(d) To create anaerobic conditions

11. Presence of phosphorus in a plant
(a) Brings about healthy root growth
(b) Retards fruit ripening
(c) Retards protein formation
(d) None of the above

12. Premature leaf fall is caused due to the deficiency of
(a) Molybdenum (b) Sulphur
(c) Sodium (d) Phosphorus

13. Most common free ion in a cell is
(a) *P* (b) *K*
(c) *Fe* (d) *B*

14. Which of the following element is a component of ferredoxin
(a) *Cu* (b) *Mn*
(c) *Zn* (d) *Fe*

15. Deficiency of iron causes
(a) Bending of leaf tip
(b) Interveinal chlorosis first on young leaves
(c) The decrease of protein synthesis
(d) Reduced leaves and stunted growth

16. Match the following and choose the correct combination from the options given

Column I		Column II
A. Potassium	1.	Constituent of ferredoxin
B. Sulfur	2.	Involved in stomata movement
C. Molybdenum	3.	Needed in the synthesis of auxins
D. Zinc	4.	Component of nitrogenase

(a) A – 2, B – 1, C – 4, D – 3
(b) A – 1, B – 2, C – 3, D – 4
(c) A – 4, B – 3, C – 2, D – 1
(d) A – 1, B – 3, C –4, D –2
(e) A – 3, B – 4, C – 1, D – 2

17. The most important role of K^+ ions is that
(a) It provides the red color
(b) It promotes photosynthesis
(c) It influences many enzymic activities which regulate many plant processes
(d) It helps in the formation of cambium

18. Chlorosis, etiolation, and albinism are caused by the deficiency of
(a) Iron, light and certain genes
(b) Zinc, iron, and magnesium
(c) Magnesium, iron, zinc, light and certain genes
(d) Magnesium, zinc, and light

19. Sinigrin pungent principle of mustard is due to
(a) Alkaloids containing cyanide radical
(b) Glycoside containing sulfur
(c) Glycoside containing an amino group
(d) Tannins containing nitrogen

20. Yellowing of tea leaf takes place by the deficiency of
(a) Chlorine (b) Potassium
(c) Oxygen (d) Sulphur

21. Deficiency symptoms of an element tend to appear first in young leaves. It indicates that the element is relatively immobile. Which one of the following elemental deficiency would show such symptoms
(a) Sulphur (b) Magnesium
(c) Nitrogen (d) Potassium

3. Micro-Nutrients

1. Which of the following element is very essential for uptake and utilization of Ca^{2+} and membrane function
(a) Phosphorus (b) Molybdenum
(c) Manganese (d) Copper
(e) Boron

2. The minerals involved in the photolysis of water are
(i) Manganese (ii) Calcium
(iii) Magnesium (iv) Chloride
(a) (i) and (ii) only (b) (i), (ii) and (iv) only
(c) (i), (ii) and (iii) only (d) (iii) and (iv) only
(e) (i) and (iv) only

3. A trace element is an element which
(a) Is a radioactive and can be traced by Geiger counter
(b) Is required in very minute amounts
(c) Draws another element out of protoplasm
(d) Was one of the first to be discovered in protoplasm

4. Micronutrients are needed in amounts equivalent to
(a) 8m mole/kg of dry matter
(b) 18m mole/kg of dry matter
(c) 25m mole/kg of dry matter
(d) 30m mole/kg of dry matter

5. Which one of the following nutrient serves as microelements for plant growth
(a) Manganese, copper, calcium, zinc
(b) Sodium, potassium, boron, chlorine
(c) Sodium, nickel, chlorine, copper
(d) Copper, molybdenum, zinc, nickel

6. The major role of minor essential elements is to act as
(a) Co-factors of enzymes
(b) Building blocks of important amino acids
(c) Constituents of hormones
(d) Binders of cell structure

7. Which one of the following symptoms are not due to manganese toxicity in plants
(a) Calcium translocation in shoot apex is inhibited
(b) Deficiency in both iron and Nitrogen is induced
(c) The appearance of a brown spot surrounded by chlorotic veins
(d) None of the above

8. Find out the correctly matched pair

	Nutrients		Functions
(a)	Zinc	–	Helps to maintain the Ribosome structure
(b)	Magnesium	–	Needed during the formation of mitotic spindle
(c)	Calcium	–	Plays a role in the opening And closing of stomata
(d)	Manganese	–	Needed in the splitting of Water to liberate oxygen during photosynthesis
(e)	Potassium	–	Needed in the synthesis of Auxin

9. Study the following lists

List-I		List-II	
(A)	Photolysis of water	(I)	Zinc
(B)	Diaz trophy	(II)	Copper
(C)	Cytochrome 'c' oxidase	(III)	Manganese
(D)	Biosynthesis of IAA	(IV)	Molybdenum
		(V)	Boron

The correct match is

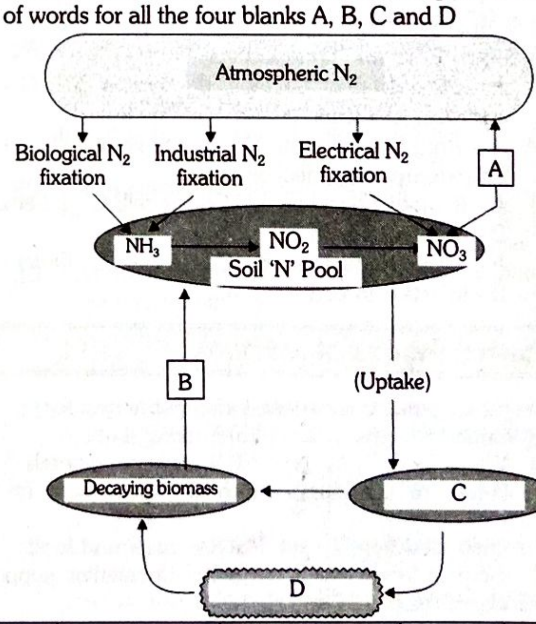
	A	B	C	D
(a)	III	II	I	V
(b)	III	IV	II	I
(c)	V	II	III	IV
(d)	IV	I	III	II

4. Mineral absorption

1. Carrier proteins are involved in
   (a) Active transport of ions (b) Passive transport of ions
   (c) Water transport (d) Water evaporation
2. Which statement is incorrect for ion–channels
   (a) They are proteins
   (b) Movement through them is simple diffusion
   (c) Movement through them is from high to low concentration
   (d) All ions pass through the same type of channel
3. Active uptake of minerals by roots mainly depends on the
   (a) Availability of oxygen
   (b) Light
   (c) Temperature
   (d) Availability of carbon dioxide
4. By which method ions are absorbed by plants
   (a) By the difference in DPD
   (b) By the difference in water potential
   (c) By carriers and pumps
   (d) By molecular diffusion
5. Which of the following shows that metabolic energy is required for the absorption of ions
   (a) More ions absorption in presence of oxygen
   (b) Less absorption of ions in presence of oxygen
   (c) More ions absorption in presence of ATP
   (d) More ions absorption in presence of NAD
6. The theory which suggests that the CO_2 produced in respiration plays an important role in mineral absorption
   (a) Contact exchange theory
   (b) Carbonic acid exchange theory
   (c) Active absorption theory
   (d) None the above
7. If the amount of an ion absorbed by a root hair cell at 0° C is 5 *gm* and at 20° C is 20 *gm*. The amount of this ion absorbed actively should be
   (a) 25 *gm* (b) 20 *gm*
   (c) 15 *gm* (d) 5 *gm*

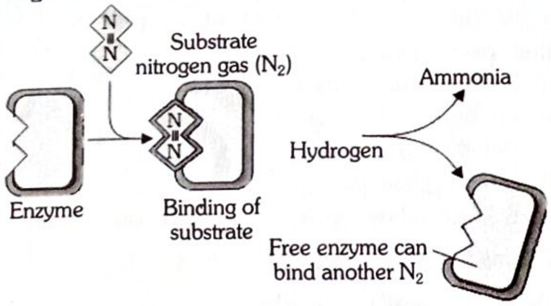
5. Nitrogen nutrition

1. In root nodules of legumes, leg-hemoglobin is important because
   (a) It transports oxygen to the root nodule
   (b) It acts as an oxygen scavenger
   (c) It provides energy to the nitrogen-fixing bacterium
   (d) It acts as a catalyst in trans-amination
2. Most of the plants obtain or absorb nitrogen from the soil in the form of
   (a) Free nitrogen gas (b) Nitric acid
   (c) Nitrite (d) Nitrates
3. Element required by the plant in large quantity is
   (a) Nitrogen (b) Calcium
   (c) Sulfur (d) Phosphorus
4. $N_2 + 8_{e-} + 8H^+ + 16ATP \rightarrow 2NH + H_2 + 16ADP + 16Pi$
   The above equation refers to
   (a) Ammonification (b) Nitrification
   (c) Nitrogen fixation (d) Denitrification
   (e) Reductive amination
5. N_2 fixation is
   (a) $N_2 \rightarrow NH_3$ (b) $N_2 \rightarrow NO_3$
   (c) $N_2 \rightarrow$ Amino acid (d) Both (a) and (b)
6. Nodules with nitrogen-fixing bacteria are present in
   (a) Cotton (b) Gram
   (c) Wheat (d) Mustard
7. Nitrates are converted to nitrogen by
   (a) Nitrogen-fixing bacteria
   (b) Ammonification bacteria
   (c) Denitrifying bacteria
   (d) Nitrifying bacteria
8. Reaction carried out by N_2 fixing microbes include
   (i) $2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H^+ + 2H_2O$
   (ii) $2NO_2^- + O_2 \rightarrow 2NO_3^-$
   Which of the following statements about these equations is not true
   (a) Step (i) is carried out by *Nitrosomonas* or *Nitrococcus*
   (b) Step (ii) is carried out by *Nitrobacter*
   (c) Both steps (i) and (ii) can be called nitrification
   (d) Bacteria carrying out these steps are usually photoautotrophs
9. With regard to the Biological Nitrogen Fixation by *Rhizobium* in association with soybean, which one of the following statement/statements do not hold true
   (a) Nitrogenase may require oxygen for its functioning
   (b) Nitrogenase is *MO-Fe* protein
   (c) Let-hemoglobin is a pink colored pigment
   (d) Nitrogenase helps to convert N_2 gas into two molecules of ammonia
10. The smallest angiospermic/dicot parasite is
    (a) Arceuthobium (b) Wolffia
    (c) Cassytha (d) Rafflesia
11. Nif genes occur in
    (a) Rhizobium (b) Aspergillus
    (c) Penicillium (d) Streptococcus
12. See the cycle and select the option which gives a correct set of words for all the four blanks A, B, C and D



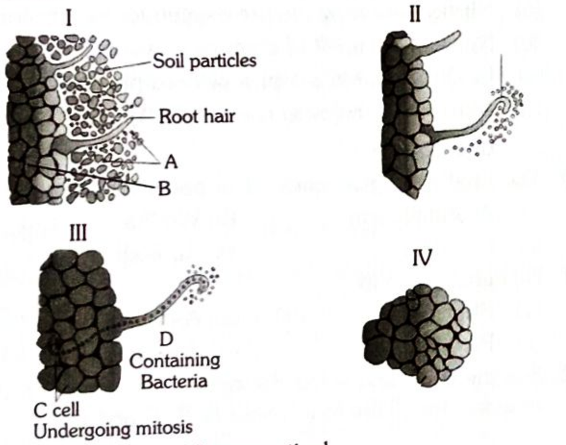
	A	B	C	D
(a)	Denitrification	Nitrification	Plants	Animals
(b)	Nitrification	Denitrification	Animals	Plants
(c)	Denitrification	Ammonification	Plants	Animals
(d)	Nitrification	Ammonification	Animals	Plants

13. The given figure represents the Nitrogen fixation. See the diagram and select the correct option



(i) Nitrogenase catalyzes the reaction
(ii) The formation of ammonia is a reductive process
(iii) One molecule of nitrogen produces two molecules of ammonia
(iv) Nitrate reductase catalyzes the reaction
(v) Formation of ammonia is an oxidative process
One molecule of nitrogen produces one molecule of ammonia
(a) III, IV, and V are correct (b) I, V and VI are correct
(c) IV, V, and VI are correct (d) I, II and III are correct

14. The given figure indicates the development of root nodule in soybean



Identify A, B, C, and D respectively
(a) A - *Nitrosomonas* bacteria; B - Cortex cell; C - Inner cortex; D - Infection thread
(b) A - *Rhizobial* bacteria; B - Endodermal cell; C - Inner Endodermis; D - Infection thread
(c) A - *Rhizobial* bacteria; B - Cortex cell; C - Inner cortex; D - Infection thread
(d) A - *Rhizobial* bacteria; B - Cortex cell; C - Outer cortex; D - Infection thread

6. Special modes of nutrition

1. The partial parasite is dependent upon the host for
(a) Support (b) Food at times
(c) Water (d) Water and minerals
2. Epiphytes are the plants which are dependent on other plants
(a) Only for water (b) For water and food
(c) Only for food (d) Only for shelter (support)
3. Majority of the orchids are
(a) Epizoic (b) Epiphytes
(c) Saprophytes (d) Parasites
4. Botanical name of the Venus Flytrap is
(a) *Aldrovanda* (b) *Dionaea*
(c) *Utricularia* (d) *Nepenthes*
5. Plants obtaining food from other plants by means of haustoria are
(a) *Symbionts* (b) *Parasites*
(c) *Hydrophytes* (d) *Saprophytes*
6. Botanical generic name of bladderwort is
(a) Drosera (b) Nepenthes
(c) Utricularia (d) Dionaea
7. A plant living symbiotically inside another plant is
(a) *Saprophyte* (b) *Endophyte*
(c) *Semiparasite* (d) *Parasite*
8. Which of the following is not an insectivorous plant
(a) *Drosera* (b) *Nepenthes*
(c) *Monotropa* (d) *Utricularia*
9. One of the following is called pitcher plant ......
(a) *Nepenthes* (b) *Aristolochia*
(c) *Drosera* (d) *Utricularia*
10. The association between ants and members of family Rubiaceae is
(a) Ornithophily (b) Entomophily
(c) Myrmecophily (d) Anemophily
11. *Santalum album* is
(a) Partial root parasite (b) Partial stem parasite
(c) Total stem parasite (d) Total root parasite
12. *Balanophora* / *Orobanche* is a
(a) Total root parasite (b) Partial root parasite
(c) Partial stem parasite (d) Total stem parasite
13. *Viscum* is
(a) Partial root parasite (b) Partial stem parasite
(c) Total root parasite (d) Total stem parasite
14. One of the following in an insectivorous plant
(a) Balanophora (b) Orobanche
(c) Rafflesia (d) Drosera
15. *Drosera* and *Sarracenia* are
(a) Symbiotic (b) Carnivorous
(c) Parasitic (d) Chemoautotrophic
16. Match the following with correct combination

Column I		**Column II**	
A.	Cuscuta	1.	Saprophyte
B.	Eichhornia	2.	Pneumatophore
C.	Monotropa	3.	Insectivorous plant
D.	Rhizophora	4.	Parasite
E.	Utricularia	5.	Root pocket

(a) A – 4, B – 3, C – 1, D – 5, E – 2
(b) A – 4, B – 5, C – 1, D – 2, E – 3
(c) A – 2, B – 3, C – 1, D – 5, E – 4
(d) A – 3, B – 1, C – 5, D – 4, E – 2
(e) A – 2, B – 5, C – 4, D – 3, E – 1
17. An obligate root parasite is
(a) Rafflesia (b) Loranthus
(c) Viscum (d) Striga
18. Which one is the largest root parasite
(a) Rafflesia (b) Monotropa
(c) Arceuthobium (d) All of these

7. NEET-AIPMT/CBSE-PMT

1. Which one of the following is not an essential mineral element for plants while the remaining three are **[2011]**
(a) Cadmium (b) Phosphorus
(c) Iron (d) Manganese
2. Which group of the element is not essential for a normal plant **[1996]**
(a) Potassium, calcium, magnesium
(b) Iron, zinc, manganese, boron
(c) Lead, nickel, iodine, sodium
(d) Magnesium, iron, molybdenum
3. Which of the following is not caused by a deficiency of mineral nutrition **[1997]**
(a) Necrosis (b) Chlorosis
(c) Etiolation (d) Shortening internode

4. Sulfur is an important nutrient for optimum growth and productivity in [2006]
(a) Fiber crops (b) Oilseed crops
(c) Pulse crops (d) Cereals

5. Which element forms part of structure of chlorophyll molecule [2003]
(a) *Fe* (b) *Mg*
(c) *K* (d) *Mn*

6. Which of the following is an essential mineral element and is not a constituent of any enzyme but stimulate the activity of many enzymes [1989]
(a) *Zn* (b) *Mg*
(c) *Mn* (d) *K*

7. The major portion of the dry weight of plants comprises of [2003]
(a) Carbon, hydrogen and oxygen
(b) Nitrogen, Phosphorus and potassium
(c) Calcium, magnesium and sulfur
(d) Carbon, nitrogen and hydrogen

8. The most abundant element present in the plants is [2004]
(a) Manganese (b) Iron
(c) Carbon (d) Nitrogen

9. Which of the following is not a macro-nutrient [1994]
Or
Which is essential for the growth of the root tip [2016]
(a) *Mn* (b) *Ca*
(c) *Mg* (d) Phosphorus

10. About 98 percent of the mass of every living organism is composed of just six elements including carbon, hydrogen, nitrogen, oxygen and [2007]
(a) Phosphorus and sulfur (b) Sulphur and magnesium
(c) Magnesium and sodium (d) Calcium and phosphorus

11. Deficiency symptoms of nitrogen and potassium are visible first in [2014]
(a) Roots (b) Buds
(c) Senescent leaves (d) Young leaves

12. In which of the following, all three are macronutrients [2016]
(a) Boron, zinc, manganese
(b) Iron, copper, molybdenum
(c) Molybdenum, magnesium, manganese
(d) Nitrogen, carbon, phosphorus

13. Minerals known to be required in large amounts for plant growth include [2015]
(a) Calcium, magnesium, manganese, copper
(b) Potassium, phosphorus, selenium, boron
(c) Magnesium, sulphur, iron, zinc
(d) Phosphorus, potassium, sulphur, calcium

14. In which of the following forms is iron absorbed by plants [2018]
(a) Both ferric and ferrous (b) Free element
(c) Ferrous (d) Ferric

15. For its activity, carboxypeptidase requires [2012]
Or
Which one is the co-factor of carbonic anhydrase
(a) Zinc (b) Iron
(c) Niacin (d) Copper

16. Which one of the following elements is not an essential micronutrient for plant growth [2007]
(a) *Mn* (b) *Zn*
(c) *Cu* (d) *Ca*

17. Which of the following is widely used metal cofactor [2003]
(a) Ca^{2+} (b) Al^{3+}
(c) Ni^{2+} (d) Mg^{3+}

18. Boron in green plants assists in [2003]
(a) Sugar transport
(b) Activation of enzymes
(c) Acting as an enzyme cofactor
(d) Photosynthesis

19. The plants accept *Zn* as [2000]
(a) Zn (b) Zn^{2+}
(c) ZnO (d) $ZnSO_4$

20. Which one of the following is not a micronutrient [2010]
(a) Boron (b) Molybdenum
(c) Magnesium (d) Zinc

21. Which of the following is micro-element in plant [1996; 2005]
(a) Manganese (b) Nitrogen
(c) Magnesium (d) Calcium

22. Which one of the following elements plays an important role in biological nitrogen fixation [1995, 2003, 2010]
(a) Molybdenum (b) Manganese
(c) Copper (d) Zinc

23. Which of the following trace element is essential for auxin synthesis in plants [2003]
(a) Molybdenum (b) Chlorine
(c) Zinc (d) Boron

24. Gray speck disease in oats takes place by the deficiency of [2003]
(a) Zinc (b) Copper
(c) Potassium (d) Manganese

25. The deficiencies of micronutrients, not only affect the growth of plants but also vital functions such as photosynthetic and mitochondrial electron flow. Among the list given below, which group of three elements shall affect most, both photosynthetic and mitochondrial electron transport [2005]
(a) Cu, Mn, Fe (b) Co, Ni, Mo
(c) Mn, Co, Ca (d) Ca, K, Na

26. Entry of mineral ions in plant root cells by diffusion is [1996]
(a) Passive absorption (b) Active absorption
(c) Osmosis (d) Endocytosis

27. Conduction of inorganic materials in plants occur mainly through **or** Minerals absorbed by roots move to the leaf through [1988]
(a) Xylem (b) Phloem
(c) Sieve tube (d) None of above

28. Which one of the following is correctly matched [2012]
(a) Passive transport of nutrients – ATP
(b) Apoplast – Plasmodesmata
(c) Potassium – Readily immobilization
(d) Bakane of rice seedlings – F. Skoog

29. For its action, nitrogenase requires [2012]
(a) High input of energy (b) Light
(c) Mn^{2+} (d) Super oxygen radicals

30. The first stable product of fixation of atmospheric nitrogen in leguminous plants is
(a) Glutamate (b) NO_2^-
(c) Ammonia (d) NO_3^-

31. A free-living nitrogen-fixing cyanobacterium which can also form a symbiotic association with the water fern *Azolla* is [2004]
(a) *Nostoc* (b) *Anabaena*
(c) *Tolypothrix* (d) *Chlorella*

32. Leguminous plants are able to fix atmospheric nitrogen through the process of symbiotic nitrogen fixation. Which one of the following statements is not correct during this process of nitrogen fixation [2010]
(a) Leghemoglobin scavenges oxygen and is pinkish in color
(b) Nodules act as sites for nitrogen fixation
(c) The enzyme nitrogenase catalyzes the conversion of atmospheric N_2 to NH_3
(d) Nitrogenase is insensitive to oxygen

33. Which two distinct microbial processes are responsible for the release of fixed nitrogen as dinitrogen gas (N_2) to the atmosphere **[2013]**
(a) Aerobic nitrate oxidation and nitrite reduction
(b) Decomposition of organic nitrogen and conversion of dinitrogen to ammonium compounds
(c) Enteric fermentation in cattle and nitrogen fixation by *Rhizobium* in root nodules of legumes
(d) Anaerobic ammonium oxidation and denitrification

34. *Cuscuta* is an example of **[2012]**
(a) Ectoparasitism (b) Brood parasitism
(c) Predation (d) Endoparasitism

35. The ability of the venus fly trap of capture insects is due to **[2005]**
(a) Chemical stimulation by the prey
(b) A passive process requiring no special ability on the part of the plant
(c) Specialized "muscle-like" cells
(d) Rapid turgor pressure changes

36. A pair of insectivorous plants is **[1999]**
(a) Drosera and Rafflesia
(b) Nepenthes and Bladderwort
(c) Dionaea and Viscum
(d) Venus flytrap and Rafflesia

8. AIIMS

1. Plants requiring two metallic compounds (minerals) for chlorophyll synthesis, are **[1986]**

Or

One mineral activates the enzyme catalase and the other is a constituent of the ring structure of chlorophyll. These minerals are respectively
(a) *Fe* and *Ca* (b) *Fe* and *Mg*
(c) *Cu* and *Ca* (d) *Ca* and *K*

2. On the basis of symptoms of chlorosis in leaves, a student inferred that this was due to the deficiency of nitrogen. This inference could be correct only if the yellowing of leaves appeared first in **[2007]**
(a) Young leaves
(b) Old leaves
(c) Young leaves followed by old leaves
(d) Old leaves followed by young leaves

3. Cytochrome oxidase has **[1992]**
(a) *Mo* (b) *Fe*
(c) *Zn* (d) *B*

4. The transfer of minerals from topsoil to subsoil through soil water is called **[1990]**
(a) Transpiration (b) Conduction
(c) Percolation (d) Leaching

5. The enzyme responsible for the reduction of molecular nitrogen to the level of ammonia in leguminous root nodule is **[2013]**
(a) Nitrogenase (b) Nitrate reductase
(c) Nitrite reductase (d) Hydrogenase
(e) Carboxylase

6. Which of the following pigments is essential for nitrogen fixation by leguminous plants **[2012]**
(a) Anthocyanin (b) Phycocyanin
(c) Phycoerythrin (d) Leghaemoglobin

7. Insectivorous plants usually grow in soils which are deficient in **[1991]**
(a) Nitrogen (b) Water
(c) Organic matter (d) *Ca/Mg*

8. *Nepenthes khasiana* is a/an **[1999]**
(a) Fungicidal and wetland plant
(b) Insectivorous and endangered/endemic plant
(c) Fungicidal and endangered plant
(d) Insectivorous and wetland plant

9. Assertion and Reason

Read the assertion and reason carefully to mark the correct option
out of the options given below:
(a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion
(c) If the assertion is true but the reason is false
(d) If both the assertion and reason are false
(e) If the assertion is false but the reason is true

1. Assertion : Leguminous plants are nitrogen fixers.
Reason : Leguminous plants have *Rhizobium* in their root nodules.

2. Assertion : Use of fertilizers greatly enhances crop productivity.
Reason : Irrigation is very important in increasing crop productivity.

3. Assertion : Deficiency of sulphur causes chlorosis in plants.
Reason : Sulphur is a constituent of chlorophyll, proteins and nucleic acids.

4. Assertion : Plants lack excretory organs.
Reason : Plant usually absorbs essential nutrients and leads a passive life.

5. Assertion : Insectivorous habitat of plants is to cope up the O_2 deficiency.
Reason : Insectivorous plants are partly autotrophic and partly heterotrophic.

6. Assertion : Hydroponics is used for solution culture.
Reason : A balanced nutrient solution contains both essential and non-essential elements.

7. Assertion : Magnesium is important in photosynthesis and carbohydrate metabolism.
Reason : Mg^{++} is involved in the synthesis of nucleic acids.

8. Assertion : Nitrogen-fixing bacteria in legume root nodules survive in oxygen-depleted cells of nodules.
Reason : Leghaemoglobin completely removes oxygen from the nodule cells.

9. Assertion : In solution culture of plants, iron is added in the form of Fe-EDTA.
Reason : Hydroponics set-up is costly.