XI
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MINERAL NUTRITION

SYLLABUS

Essential minerals, macro and micronutrients and their role; Deficiency symptoms; Mineral toxicity; Elementary idea of Hydroponics as a method to study mineral nutrition; Nitrogen metabolism-Nitrogen cycle, biological nitrogen fixation.

KEY CONCEPTS

INTRODUCTION

* Organisms require many organic and inorganic substances to complete their life cycle. All such substances which they take from outside constitute their nutrition. On the basis of their nutritional requirements, organisms can be classified into heterotrophs and autotrophs.
* All non-green plants and animals, including human beings, are heterotrophs. Autotrophic green plants obtain their nutrition from inorganic substances which are present in soil in the form of minerals, which are known as mineral elements or mineral nutrients and this nutrition is called **mineral nutrition**.
* The inorganic nutrients are classified as essential elements and non essential elements.
* **17 elements** have been placed under essential elements.
* These are the elements without which the reproduction and life cycle of a plant cannot be completed.
* The essential elements are : C, H, O, N, P, K, S, Mg, Ca, Fe, Mo, Mn, Ni, Zn, B, Cl, Cu.

General functions of mineral elements :

* **Frame work elements** – Form carbohydrates which form cell wall, e.g., C, H, O.
* **Protoplasmic elements** – Form protoplasm, e.g., C, H, O, N, P, S.
* **Catalytic elements –** e.g., Fe, Cu, Zn, Mo, Mg, Mn, K (activator of over 40 enzymes)
* **Balancing element** – Ca, Mg and K counteract the toxic effect of other minerals.
* **Storage elements** – C, N, S, P.
* **Critical elements** – N, P, K.
* Minerals influence OP and TP.
* Monovalent cations (Na^+, K^+) increases permeability of membrane, while divalent and trivalent ions decrease it.
* **Toxic elements** e.g., Al, As, Hg, Pb, Ag.
* **Functional elements:** They are non essential in most plants but have a definite activity in some species e.g., silicon in grasses.

METHODS TO STUDY THE MINERAL REQUIREMENTS OF PLANTS

* Soils normally contain sufficient quantities of essential minerals.
* However, three important elements need to be replenished in crop fields as they are depleted by repeated cultivation.
* These fertiliser elements called **critical elements** are **nitrogen**, **phosphorus** and **potassium** (NPK).

* The common sources of these elements used in India are: nitrate of sodium, ammonium sulphate, ammonium nitrate, ammonium chloride, urea, etc.
* The NPK fetilisers comprising bags of fertilisers are labelled 17-18-19 or 15-15-15 or other combinations.
* These numbers refer to the percentage by weight of nitrogen, phosphorus and water soluble potassium.
* To determine the elements essential for plant growth and deficiency symptoms of an essential element, well defined nutrient medium has to be used. Seeds are grown in highly washed pure sand in a glass or glazed procelain or plastic container and supplied with a carefully made up nutrient solution.
* **Arnon and Hoagland's Medium** prescribed a medium containing micronutrients.
* Iron was earlier supplied as ferrous sulphate, but it often precipitated out.
* This problem has now been solved by dissolving the ferrous sulphate along with a **chelating agent Na-EDTA** (disodium salt of ethylene diaminetetra acetic acid.)

Solution Culture

* It is performed in glass jars or polythene bottles.
* The container is covered with black paper after pouring solution into them.
* Black paper has two functions -(a) Prevention of growth of algae (b) Prevention of reaction of roots with light.
* Seeds are allowed to germinate over split cork.
* Cotyledons are removed after seedling formation.
* The plant is properly supported with the help of split cork.
* Solution is aerated at regular intervals and is changed after 2-3 days.

Hydroponics :

* Commercial technique of soil less culture is called **Hydroponics**, which was first developed by Goerick (1940).
* In 1860, **Julius von Sachs**, a German botanist, demonstrated for the first time, that plants could be grown to maturity in a defined nutrient solution in complete absence of soil.
* Culture is performed in large tanks of metal or **Reinforced Cement Concrete** (R.C.C.) Tanks are covered with wire mesh.
* Tanks are provided with aerating and circulating techniques.
* Seeds are suspended in solution from the wire mesh with the help of threads.
* As plant grows up additional support is provided.

Significance

* Useful in areas having thin, infertile and dry soils.
* It can regulate the pH at optimum for a particular crop.
* It controls soil borne pathogens.
* It avoids problem of weeding.
* Out of season vegetables (like tomato, seedless cucumber, lettuce) and flowers can also be obtained.

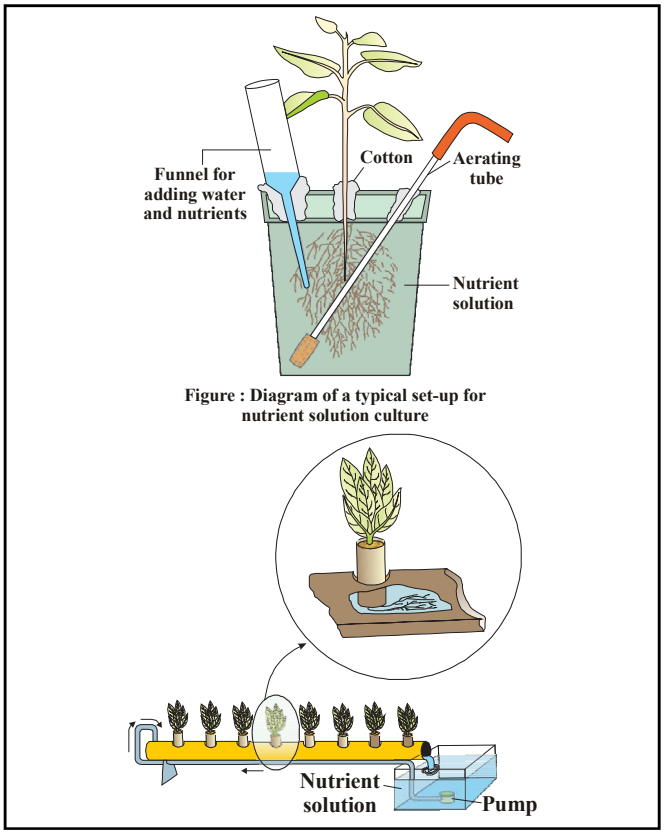


Figure : Diagram of a typical set-up for nutrient solution culture

Figure : Hydroponic plant production.
Plants are grown in a tube or trough placed on a slight incline. A pump circulates a nutrient solution from a reservoir to the elevated end of the tube. The solution flows down the tube and returns to the reservoir due to gravity. Inset shows a plant whose roots are continuously bathed in aerated nutrient solution. The arrows indicates the direction of the flow.

MINERAL NUTRITION

* About 50-60 elements are present in plant body but only 16-17 elements are considered as essential elements.
* **Criteria of essentiality of minerals :**

(i) The element must be necessary for normal growth and reproduction of all plants.

(ii) The requirement of the element must be specific for plant life. That is element indepensable to plant.

(iii) The elements must be directly involved in metabolism of plant.

Types of Essential Elements

* On the basis of concentration in plant, **Hoagland** divided essential elements into two groups.
* **Macronutrients** are generally present in the plants tissues in large amount (in excess of 10 mmole Kg^{-1} of dry matter).
* **Micronutrients** or trace elements are needed in very small amounts (less than 10 mmole Kg^{-1} of dry matter)
* Both macro-nutrients (N,P,K, S, etc.) and micro-nutrients (Cu, Zn, Fe, Mn, etc.) form components of fertilisers and are applied as per need.
* **Macronutrients v/s Micronutrients**

S.N.	Macronutrients	Micronutrients
1.	These are nutrient elements 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 m mole kg^{-1} of dry matter.	The concentration of a microelement is less than 10 m mole 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).

* **Four group of essential elements :**

(i) As components of **biomolecules** and forms structural elements of cells (e.g. carbon, hydrogen, oxygen and nitrogen)

(ii) As components of **energy-related** chemical compounds in plants. (magnesium in chlorophyll and phosphorous in ATP)

(iii) Element that **activate** or **inhibit enzymes** (Mg^{2+}, Zn^{2+})

(iv) Alter the **osmotic potential** of a cell. (K^{+})

Deficiency symptoms :

* The concentration of the essential element below which plant growth is retarded is called as Critical concentration.
* Morphological changes that are observed due to deficiency (below Critical Concentration) of a particular element are called as deficiency symptoms.
* The deficiency symptoms of highly mobile elements in plants like N, P, K, Mg first appear in older plant parts. These minerals are present as structural constituent of biomolecules of mature plant parts and when plant parts become older these biomolecules are broken down making these elements available for younger plant parts.
* The deficiency symptoms of immobile elements like Ca, S are first appear in young plant parts, as they are not transparted from older plant parts.
* **Chlorosis** (loss of chlorophyll)- yellowing of leaves caused due to deficiency of N,K, Mg, S, Fe, Mn, Zn & Mo.
* **Necrosis** (Death of tissues)-caused due to deficiency of Ca, Mg, Cu, K.
* **Inhibition of cell division-** caused due to deficiency of K, N, & Mo.
* **Delay in flowering**-caused due to deficiency in N, S, and Mo.

Micronutrients can be toxic

* Mineral ion concentration. in tissues that reduces the dry weight of tissues by about 10% is called as toxic.
* Moderate decrease in micronutrients causes deficiency symptoms and moderate increase causes toxicity.
* It may be that excess of an element (toxicity) may inhibit the uptake of another element.
* Prominent symptom of manganese toxicity is the appearance of **brown spots** surrounded by chlorotic veins.

Manganese competes with iron and magnesium for uptake and with magnesium for binding with enzymes. Manganese also inhibit calcium translocation in shoot apex.

Therefore, excess of manganese may, in fact, induce deficiencies of iron, magnesium and calcium. Thus, what appears as symptoms of manganese toxicity may actually be the deficiency symptoms of iron, magnesium and calcium.

SPECIFIC ROLES OF DIFFERENT ELEMENTS

Mineral Element	Principl Functions	Deficiency symptoms
1. Nitrogen NO_3^-/Nitrate form	(a) All living matter (b) Amino acids, proteins (c) Purines, pyrimidines (d) Early defoliation (e) NAD, NADP, FMN, FAD (f) Chlorophyll, cytochromes	**Chlorosis** first in older leaves, premature leaf fall reduced yield. Development of anthocyanin pigment **(Mottled chlorosis)**
2. Phosphorus $H_2PO_4^-$ & HPO_4^- orthophosphate anion form	(a) Nucleic acids (b) Nucleoproteins (c) Phspholipids (d) AMP, ADP, ATP, (e) NAD, NADP (f) Indispensible role in energy metabolism	Chlorosis with necrosis, **premature abscission of leaf,** poor vasculature.
3. Potassium K^+ in free form	(a) Permeability (b) Osmotic regulation and hydration (c) Commonest free ion in cell (d) Stomatal movements (e) Translocation of sugars (f) Enzymes concerned with photosynthesis, nitrate reduction, protein bio -synthesis, respirations, etc	**Mottled chlorosis,** premature death, **loss of apical dominance** lodging in cereals. Bushy habit. Cotton rust
4. Calcium Ca^{++} form	(a) Cell wall Structure (b) Membrane structure (c) Influence nitrate reductase (d) In ion transport (e) In cell elongation and spindle formation (f) Activators of amylases, adenyl kinase, ATPase, etc.	Stunted growth, **degeneration of meristems,** chlorosis, curling first in young leaves. Black heart of *Celery*.
5. Magnesium Mg^{++} form	(a) Component of chlorophyll (b) Activators of a number of photosynthetic and respiratory enzymes (c) Combiness the subunits of ribosomes (d) Synthesis and hydrolysis of ATP	Marginal curling, interveinal chlorosis with anthocyanin accumulation first appearing in older leaves. 'Sand drown' of Tobacco.
6. Sulphur SO_4^{2-} form (Sulphate)	(a) Part of CoA, Ferredoxin, Vit. H, Thiamine, Lipoic acid. (b) Amino acids e.g. Cysterine, Cystine, methionine	Chlorosis first in young leaves, reduced nodulation in legume. **Tea yellow,** extensive root system.

7. Iron Fe^{++}/Fe^{+++} Form	(a) Structural component of porphyrin molecules, cytoch -romes, catalase, peroxidase leghaemoglobin	**Interveinal chlorosis** first in young leaves. Green Netting of Citrus.
8. Molybdenum MoO_4^{2-} form	(a) Component of nitrate reductase (b) Important in N_2 fixation	Mottled chlorosis, **whiptail of cauliflower,** loosening of inflorescence of cauliflower. Scald of beans.
9. Boron H_3BO_3/BO_3^{-3} (Borate) form	(a) Translocation of sugars (b) For seed, pollen and spore germination (c) Enzymes of phosphorylation (d) RNA metabolism (e) Phenol metabolism and cell differentiation (f) Regulates pentose phosphate pathway (g) Flowering and fruiting (h) For uptake and utilisation of Ca^{+2}.	**Brown heart of turnip**, **internal cork** of apple, **heart rot** of sugarbeet, decreased nodulation in legumes. Hollow stem of caulifilower, stem crack of *Celery*.
10. Copper Cu^{++} form	(a) Oxidase enzyme: tyrosinase plastocyanin, cytochrome oxidase and ascorbic acid oxidase.	**Dieback, exantheme, reclamation disease,** blackening of potato, tubers, chlorosis
11. Manganese Mn^{++} form	(a) In chlorophyll synthesis (b) In photolysis of H_2O in phtosynthesis (c) Maintenance of chloroplast membrane structure (d) Enzyme systems; RNA polymerase, NAD-malic enzyme in C_4 plants	Interveinal chlorosis, **grey speck** of oat, **marsh spot disease of pea**.
12. Zinc Zn^{++} form	(a) Tryptophan synthesis (precursor of auxin) (b) Dehydrogenase enzymes, pyriding nucleotide, alcohol, glucose-6-p & triose phosphate (c) Carbonic anhydrase (d) Promotes synthesis of cytochromes (e) Stabilizes ribosomal fractions.	**Little leaf,** leaf rosettes leaf malformations. White bud, whip tip of maize, sickle leaf of cocao, **khaira disease of rice.**
13. Chlorine	(a) In the transfer of electron from water to PS ll (Photolysis) (b) Maintain cation-anion balance	Bronze colour in leaves, chlorosis, necrosis, swollen root flower abscission.
14. Nickel	(a) Urease and hygrogenase activity	It helps in germination and early seeding growth of Jack Bean seeds. It causes necrotic spots.

MECHANISM OF ABSORPTION OF ELEMENTS

The process of absorption can be demarcated into two main phases.

* In the first phase, an initial rapid uptake of ions into the 'free space' or 'outer space' of cells – the apoplast, is passive.
* In the second phase of uptake, the ions are taken in slowly into the 'inner space' – the symplast of the cells. The passive movement of ions into the apoplast usually occurs through ion-channels, the trans-membrane proteins that function as selective pores. On the other hand, the entry or exit of ions to and from the symplast requires the expenditure of metabolic energy, which is an active process. The movement of ions is usually called **flux**; the inward movement into the cells is influx and the outward movement, efflux.

Factors affecting mineral absorption

The process of mineral absorption is influenced by the following factors :

* **Temperature :** The rate of absorption of salts and minerals is directly proportional to temperature.
  The absorption of mineral ions is inhibited when the temperature has reached its maximum limit, perhaps due to denaturation of enzymes.
* **Light :** When there is sufficient light, more photosynthesis occurs. As a result more food energy becomes available and salt uptake increases.
* **Oxygen :** A deficiency of O_2 always causes a corresponding decrease in the rate of mineral absorption. It is probably due to unavailability of ATP. The increased oxygen tension helps in increased uptake of salts.
* **pH :** It affects the rate of mineral absorption by regulating the availability of ions in the medium. At normal physiological pH monovalent ions are absorbed more rapidly whereas alkaline pH favours the absorption of bivalent and trivalent ions.
* **Interaction with other minerals :** The absorption of one type of ions is affected by other type.

The absorption of K^+ is affected by Ca^{++}, Mg^{++} and other polyvalent ions. It is probably due to competition for binding sites on the carrier. However, the uptake of K^+ and Br^- becomes possible in presence of Ca^{++} ions. There is mutual competition in the absorption of K, Rb and Cs ions.

Growth : A proper growth causes increase in surface area, number of cells and in the number of binding sites for the mineral ion. As a result, mineral absorption is enhanced.

N_2 METABOLISM

Role of Nitrogen in Plants:

* Constituent of proteins, nucleic acids ATP, GTP, Vitamins, chlorophyll, alkaloids, cytochromes, hormones.
* Nitrogen is necessary to plants for heridity, reproduction, growth metabolism and development.

Sources of Nitrogen to plants :

(1) Atmospheric nitrogen:

* $N \equiv N$ (Molecular, inert or elemental form) used by Rhizobium (Legumes), BGA, Lichens.
* These **converts atm. N_2 into metabolically usefull ammonia(NH_3).** This process is called as biological nitrogen fixation.

(2) NO_3^-, NO_2^-, NH_4^+ in soil:

These are major source of nitrogen to plants.

* **Nitrate ions (NO_3^-)** are **cheif form of nitrogen used by majority of plants.**
* Plants grow in acidic soil & found in forest use ammonium ions (NH_4^+) as major N_2 source.
* Nitrate ions are cheif source of N_2 for plants but they can not be used directly in metabolic pathway in plant cells, as it is highly oxidised form. so NO_3^- (Nitrate) first converted into NO_4^+ **(ammonium ions)** called **nitrate reduction**. So NH_4^+ ions enters in plant metabolism.

(3) Organic nitrogen in soil: as amino acids, protein body.
Due to death & decay of organisms. This is not a major source of N_2.

(4) Insect bodies: for some plants (insectivorous plants)

(5) Urea as chemical/artificial fertilizers.

Nitrogen (N_2) Cycle:

(1) Biological Nitrogen Fixation/Diazotrophy ($N_2 \rightarrow NH_3$):- Conversion of molecular or elemental nitrogen (N ≡ N) into inorganic nitrogenous compounds (NH_3) through agency of living organisms is called as **biological nitrogen fixation** or **Diazotrophy**

Nitrogen Fixing organisms (Diazotrophs): Free living diazotrophs carry out diazotropy only in free living condition while symbiotic diazotrophs only in symbiotic condition.

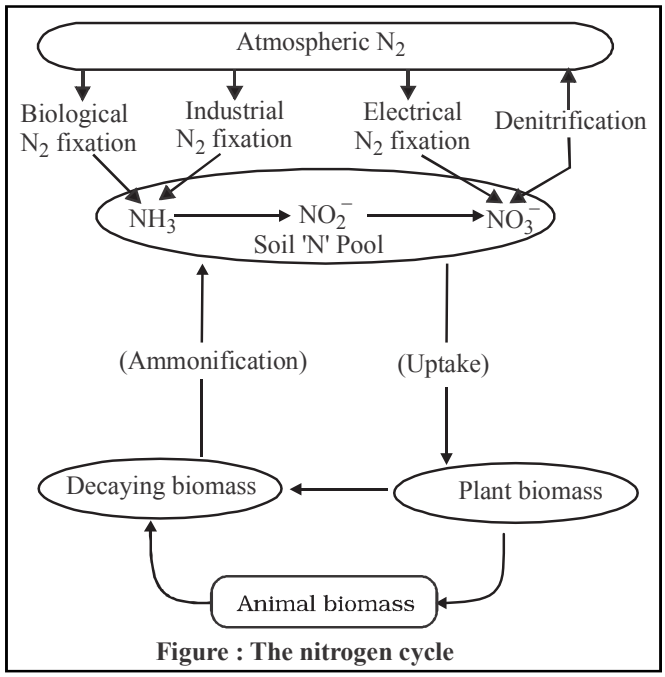


Figure : The nitrogen cycle

Some important N_2 fixing organisms

(a) Asymbiotic N_2 fixers:

Bacteria

* **Aerobic** – *Azotobacter, Beijerinckia*
* **Facultative Aerobic** – *Klebsiella, Bacillus*
* **Anaerobic** – *Clostridium*
* **Photosynthetic**–*Chromatium, Rhodospirillum*

Blue Green Algae – Anabaena, Aulosira, Nostoc, Scytonema etc. Heterocyst is present in these blue green algae which is responsible for N_2 fixation.

(b) Symbiotic N_2 fixers:

* In root nodule of legumes – *Rhizobium*
* In root nodule of *Alnus, Casuarina, Myrica* – *Frankia*
* In leaf nodule of *Dioscorea, Pavetta and Psychotria* – *Klebsiella*
* In coralloid root of *Cycas* – *Anabaena cycadae*
* In fronds of *Azolla* – *Anabaena azollae*
* In thallus of *Anthoceros* – *Nostoc*

(c) Intermediate: Loose symbiosis with the roots of *Sorghum, Zea* etc. *by Azospirillum.*

(2) Ammonification:

* Conversion of dead organic nitrogenous compounds into ammonia.
* It is carried out by decay causing organisms such as *Bacillus ramosus, B. vulgaris, Acthomyces,* 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.

(3) Nitrification: Oxidation of ammonia, produced by ammonification **into nitrates** by **nitrifying bacteria** is called as nitrification.

(i) $2NH_3 + 2O_2 \xrightarrow{\text{Nitrosomonas}} 2NO_2^- + 2H_2O + 2H^+$

Ammonia — Nitrite ion

(ii) $2NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} 2NO_3^-$

Nitrate ions

* 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 autotrops 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 formes the amine group of amino acids.
* Some fungi like **Aspergillus**, **Penicillium** can also carry out this process.

(4) Denitrification:

* Nitrates or nitrites converts back into molecular or atmospheric nitrogen by **denitrifying bacteria** is denitrification.
* Denitrification is carried out by bacteria *Pseudomonas denitrificans* and *Thiobacillus denitrificans*

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

The released N_2 escapes into the atmosphere.

(5) Nitrate reduction: Plants take nitrogen from soil, chiefly in nitrate forms which converts into ammonia by following method.

$$NO_3^- \xrightarrow{\text{Nitrate reductase (Cytoplasm)}} NO_2^- \xrightarrow{\text{Nitrite reductase (Plastid)}} NH_4^+$$

* Enzyme nitrogenase is a Mo-Fe protein and catalyse the conversion of atm. N_2 to NH_3. It posses two units unit-Ist is Mo-Pe protein and unit-IInd is Fe-S protein
* Nitrogenase is extremely sensitive to oxygen. So to protect it from oxygen, nodules contains an **O_2 scavanger** called **leghaemoglobin (Lhb)** and combined with O_2 to form oxyleghaemo-globin.
* **Leghaemoglobin is pink in colour** & similar to haemoglobin of vertebrates. Globin part synthesised by plant and heam part by bacteria.

Nodule formation :

* It is due to interactions between bacteria and host root. It occurs in following steps:
* **Multiplication & colonization of Rhizobia** at Rhizosphere and attachment to epidermal root hair cells. Initial attraction of Rhizobia to host root is **chemotactic** (Rhicadhesin protein of bacterial cell identify host root) as **root exude amino acids, sugars, organic acids** and **flavonoids**.
* **Characterstic curling of root hairs and invasion of the bacteria** to form an **infection thread,** by the invegination of plasma membrane of root hair cells and it reaches up to the cortex of roots.
* Curling of root hairs is stimulated by **specific complex polysaccharides found on the surface of rhizobia,** recognised by **Lectins (small proteins of host plant roots).**
* **Nodule initiation & development in root cortex. Mitogenic agents secreted (Kinetin) by bacteria & auxin produced by plant cell promotes cell division & extension** leading to nodule formation.
* Nodule establishes direct vascular connection with host for exchange of nutrients. Root nudule cells have chromosome in double as compare to other somatic cells. Thus nodule cells are polyploid specially **Tetraploid**.
* **Release of bacteria from infection thread** and they differentiate as specilized nitrogen fixing cell.
* Bacteria continue to multiply during it's path in root thair cells & bacteria distribute in most of cells.
* The membrane of infection thread bud off to form small vesicles which contain one or more bacteria. Then bacteria stop dividing & enlarge & differentiate in **nitrogen fixing cells called bacteroid** & it's membrane called **peribacteroid membrane.**

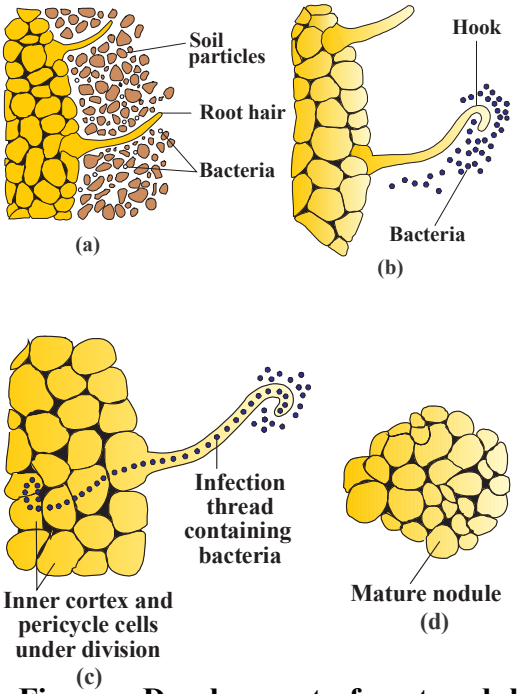


Figure : Development of root nodules in soyabean

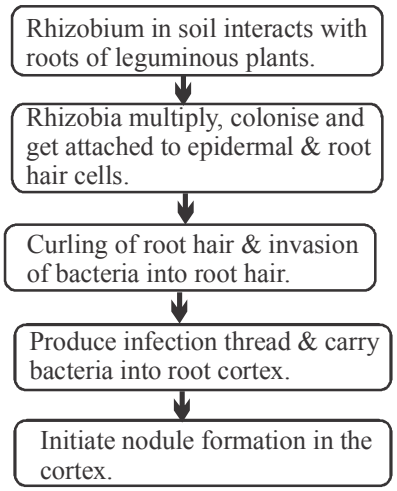


Figure : Steps of Nodule Formation

Mechanism of Biological N_2 fixation

* By Burris. The atm. N_2 is reduce by the addition of hydrogen atoms.
* The three bonds between two nitrogen atoms $N \equiv N$ or dinitrogen are broken & ammonia (NH_3) is formed by reduction of $N \equiv N$ and then reduction of ammonia (NH_3) to form ammonium ions (NH_4^+).

N_2 fixation requires 3 components :

(i) A strong reducing agent - $NADPH_2/FADH_2/NADH_2$ - from photosynthesis & respiration.

(ii) ATP to transfer hydrogen atom to dinitrogen - from respiration & photosynthesis.

(iii) Nitrogenase enzyme (Formed by nif gene).

$$N_2 + 8e^- + 8H^+ + 16ATP \rightarrow 2NH_3 + H_2 + 16\ ADP + 16\ P_i$$

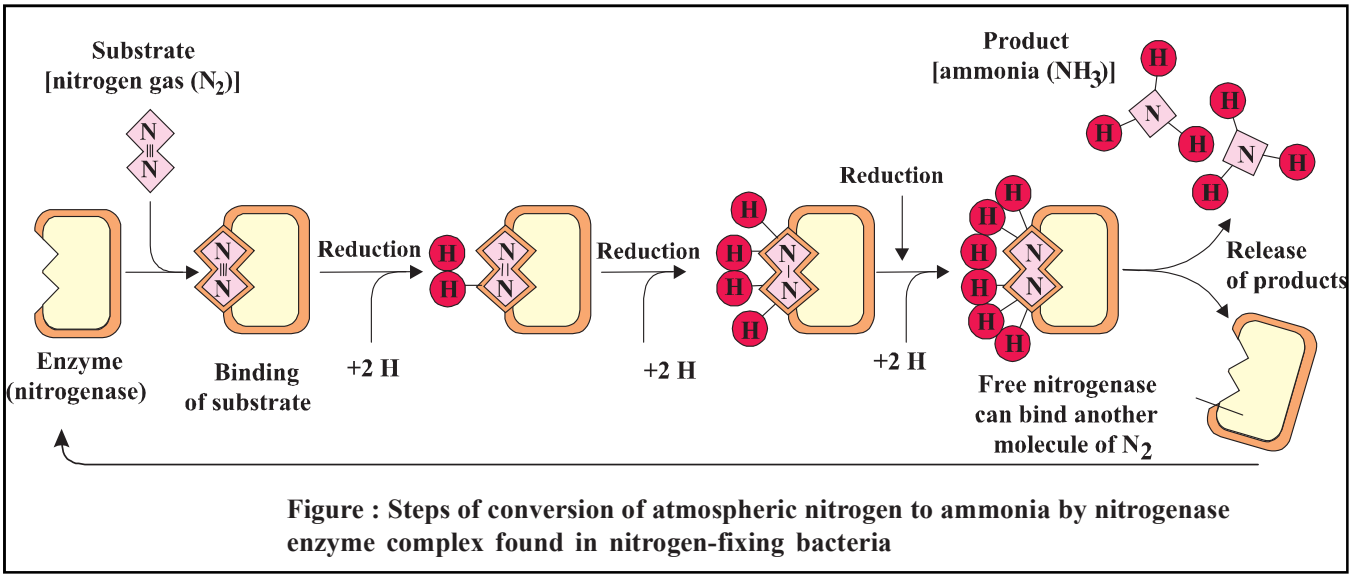


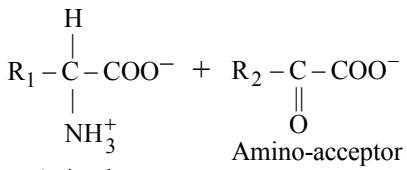
Figure : Steps of conversion of atmospheric nitrogen to ammonia by nitrogenase enzyme complex found in nitrogen-fixing bacteria

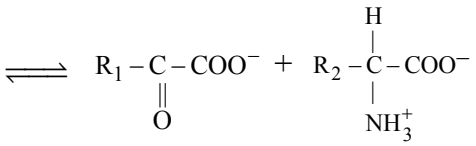
Fate of ammonia :

* At physiological pH, the ammonia is protonated to form NH_4^+.
* Most of plant assimilated nitrate and ammonium ions.
* **Reductive amination**: the ammonia reacts with α-ketoglutaric acid and forms Glutamic acid. A reduced coenzyme (NADPH) is required.

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

* **Transamination:** it involves the transfer of amino group from one amino acid to the keto group of a keto acid.





Example : Glutamic acid + Oxaloacetic acid

$$\xrightarrow[\text{Aminotransferase}]{\text{Glutamate Aspartate}} \alpha\text{-ketoglutaric acid} + \text{Aspartic acid}$$

* Glutamic acid is the main amino acid from which by the process of transamination other amino acids are synthesized.
* Two important amides – asparagines and glutamine found in the protein of plant.
* They are formed from two amino acids namely aspartic acid and Glutamic acid respectively.
* Amides contain more nitrogen than the amino acids, they are transported to other parts of the plant via xylem vessels. In addition, along with the transpiration stream the nodules of some plants (e.g., soyabean) export the fixed nitrogen as ureides (degraded urea). These compounds also have a particularly high nitrogen to carbon ratio.

Transportation of assimilated N_2 :

* In plants transportation of assimilated N_2 through xylem occurs mainly in form of amides (Glutamine and Asparagine), especially in leguminous plants.

* Amides are more stable than amino acids and posses high nitrogen to carbon ratio (2N to 5C in glutamine, while glutamic acid posses 1N to 5C).
* Formation of amides from amino acids by the addition of amino group, (The hydroxyl part of acid replaced by NH_2 radicle) catalysed by enzyme and is called **Catalytic amidation**.
* In Soyabean, Ureides are translocated in non nodulated plant parts.

CONCEPT REVIEW

* Plants obtain their inorganic nutrients from air, water and soil.
* Plants absorb a wide variety of minerals elements.
* Not all the mineral elements that they absorb are required by plants.
* Out of the more than 105 elements discovered so far, less than 21 are essential and beneficial for normal plant growth and development.
* The elements required in large quantities are called **macronutrient** while those required in less quantities or in trace are termed as **micronutrients**.
* These elements are either essential constituents of proteins, carbohydrates, fats, nucleic acid etc. and/or take part in various metabolic processes.
* Deficiency of each of these essential elements may lead to symptoms called **deficiency symptoms**.
* Chlorosis, necrosis, stunted growth, impaired cell division, etc. are some prominent deficiency symptoms.
* Plants absorb minerals through roots by either passive or active processes.
* They are tarried to all parts of the organism through xylem along with water transport.
* N_2 is very essential for the sustenance of life.
* Plants cannot use atmospheric nitrogen directly.
* But some of the plants in association with N_2-fixing bacteria, especially roots of legumes, can fix this atmospheric nitrogen into biologically usable forms.
* Nitrogen fixation requires a strong reducing agent and energy in the form of ATP.
* N_2-fixation is accomplished with the help of nitrogen fixing microbes, mainly *Rhizobium*.
* The enzyme nitrogenase which plays an important role in biological N_2-fixation is very sensitive to oxygen. Most of the processes take place in anaerobic environment.
* The energy ATP, required is provided by the respiration of the host cells.
* Ammonia produced following N_2-fixation is incorporate into amino acids as the amino group.
* Free-living nitrogen fixing aerobic microbes are ***Azotobacter*** and ***Beijernickia.***
* Free-living nitrogen fixing anaerobic microbes are ***Rhodospirilium.***
* A number of cyanobacteria like ***Anabaena*** and ***Nostoc*** are free-living nitrogen fixer.
* Best example of symbiotic nitrogen fixation is observed in legume-Rhizobium bacteria.
* Rhizobium form root nodules in leguminous plants.
* ***Frankia*** also produces nitrogen-fixing nodules on the roots of non-leguminous plants (e.g. Alnus).
* Both Rhizobium and Frankia are free living in soil, but as symbiont, can fix atmospheric nitrogen.
* The root nodules contain pink coloured pigment contains a protein called **leg-haemoglobin.**
* Nitrogenase is highly sensitive to molecular oxygen; it requires anaerobic condition.
* Leg-haemoglobin acts as **oxygen scavenger** and provides anaerobic condition to the bacteria inside the nodules; protect the enzyme nitrogenase from oxidation.
* Ammonia synthesis by nitrogenase is energetically expensive process; 8 ATP required synthesizing each molecule of NH_3.
* Chlorosis is caused by the deficiency of elements N, K, Mg, S, Fe, Mn, Zn and Mo.
* Necrosis is due to the deficiency of Ca, Mg, Cu, K.
* Lack or low level of N, K, S, Mo causes an inhibition of cell division.
* N, S, Mo elements delay flowering if their concentration in plants is low.
* Mg present in chlorophyll as non-ionic form (as Fe in Hb)
* Mg remains after chlorophyll burning.

* **Role of macro and micro-nutrients :**

Category of Nutrients	Name of element	Form in which absorbed by plants	Functions Role played
Macro nutrients	1-Nitrogen	NO_3^-, NO_2^- or NH_4^+	Major constituent of Proteins, nucleic acids, vitamins and hormones.
	2-Phosphorus	$H_2PO_4^-$ or HPO_4^{2-}	Constituent of cell membranes nucleic acids, nucleotides & required for all phosphory-lation reactions.
	3-Potassium	K^+	Maintains anion-cation balance in cells. involved in protein synthesis, opening and closing of stomata, turgidity of cells.
	4-Calcium	Ca^{2+}	Required for permeability of cell membrane, formation of mitotic spindle, formation of middle lamella.
	5-Magnesium	Mg^{2+}	Constituent of chlorophyll, maintains structure of ribosome, activates enzymes of respiration & photosynthesis, involved in DNA & RNA synthesis.
	6-Sulphur	SO_4^{2-}	Constituent of amino acid (Methionine & Cysteine), several Co-enzymes, ferredoxin &Vitamins (Biotin, Thiamine & CoA.
Micro nutrients	1-Iron	Fe^{3+}	Constituent of proteins involved in electron transfer (ferredoxin, cytochromes). activates catalase enzyme and essential for formation of chlorophyll.
	2-Manganese	Mn^{2+}	Necessary for photolysis of water in photosynthesis, activates enzymes involved in photosynthesis, respiration & nitrogen metabolism.
	3-Zinc	Zn^{2+}	Required for synthesis of auxin. activates carboxylases.
	4-Copper	Cu^{2+}	Required for over all metabolism, associated with enzymes involved in redox reactions.
	5-Boron	BO_3^{3-}, $B_4O_7^{2-}$	Required for uptake& utilization of Ca^{+2} membrane functioning, pollen germination cell elongation, cell differentiation and carbohydrate translocation.
	6-Molybdenum	MoO_2^{2-}	Component of nitrogenase and nitrate reductase enzymes.
	7-Chlorine	Cl^-	Anion-Cation balance in cell, necessary for photolysis of water in photosynthesis.

IMPORTANT POINTS

* Boron is necessary for translocation of sugars in plants.
* Deficiency of molybdenum causes mottling and marginal necrosis of leaves.
* Phosphorus brings about healthy root growth.
* Nitrogen fixing bacteria were discovered by Winogradsky.
* Element essential for photolysis of water is chlorine.
* Plant require Fe and Mg for synthesis of chlorophyll.
* Plants detoxify heavy metals by means of phytochelatins.
* Deficiency of sulphur causes chlorosis in plants.
* An element essenstial as electron carrier is iron.
* *Bacillus* and *Rhodospirullum* are free living nitrogen fixing bacterium but *Rhizobium* is not.
* C, H, O, N, P is main constituents of protoplasm (organic materials). So they called protoplasmic elements. C, N & O from atmosphere and H_2O from soil for H & O.
* C, H, O is main components of nucleic acid, proteins, enzymes, carbohydrates, fats. (Frame work elements)
* Most of soil deficient of NPK and these elements are known as critical elements, NPK-fertilizer is good for crop yield.
* Silica (SiO_2) is present in cell wall of diatoms grasses and paddy straw.
* Mo require in minimum quantity.
* Plants grown in moistened air with nutrients is Aeroponics.
* Root meristem is important in storage & absorption of minerals.
* Na^+ found in halophytes for their growth (marine plants).
* Trace element are micro-nutrients while tracer-elements are radio-isotopes.

QUESTION BANK

EXERCISE - 1 (LEVEL-1) [NCERT EXTRACT]

SECTION - 1 (VOCABULARY BUILDER)

Choose one correct response for each question.

For Q.1-Q.4

Match the column I with column II.

Q.1

	Column I	Column II
a.	Manganese	i. Macronutrient
b.	Magnesium	ii. Component of biomolecules
c.	Phosphorus	iii. Micronutrient
d.	Nitrogen	iv. In formation of ATP

Codes

(A) a-iii, b-i, c-iv, d-ii (B) a-iv, b-iii, c-ii, d-i

(C) a-iii, b-ii, c-i, d-iv (D) a-i, b-ii, c-iii, d-iv

Q.2

	Column I	Column II
a.	Found in some amino acids	i. Mg
b.	Required for photolysis of water	ii. I
c.	Not important for plants	iii. S
d.	Structural component of chlorophyll	iv. Mn

Codes

(A) a-iv, b-i, c-ii, d-iii (B) a-iii, b-iv, c-i, d-ii

(C) a-i, b-ii, c-iv, d-iii (D) a-iii, b-iv, c-ii, d-i

Q.3 Match each of the following type of bacteria with their role in providing nitrogen to the plants.

	Column I	Column II
a.	Nitrogen-fixing bacteria	i. Bacteria that are able to decompose dead organic matter in the soil to ammonium.
b.	Ammonifying bacteria	ii. Bacteria that are able to convert atmospheric nitrogen to ammonium.
c.	Nitrifying bacteria	iii. Bacteria that are able to convert ammonium to nitrates for plants to absorb.
d.	Bacteroids	iv. Enlarged, immobile bacteria in the legume root nodules.

Codes

(A) (a) - ii, (b)-i, (c)-iii, (d)-iv

(B) (a) - i, (b)-ii, (c)-iii, (d)-iv

(C) (a) - iv, (b)-iii, (c)-ii, (d)-i

(D) (a) - i, (b)-iii, (c)-ii, (d)-iv

Q.4

	Column I	Column II
a.	Potassium	i. Help in translocation of sugars.
b.	Molybdenum	ii. Involved in synthesis of auxin.
c.	Boron	iii. Involved in stomatal movement.
d.	Zinc	iv. Constituent of ferredoxin
e.	Sulphur	v. Component of nitrate reductase

Codes

(A) (a) - iii, (b)-iv, (c)-ii, (d)-i, (e)-v

(B) (a) - iii, (b)-v, (c)-i, (d)-ii, (e)-iv

(C) (a) - i, (b)-ii, (c)-iii, (d)-iv, (e)-v

(D) (a) - ii, (b)-iii, (c)-v, (d)-i, (e)-iv

SECTION - 2 (BASIC CONCEPTS BUILDER)

For Q.5 to Q.23 :

Choose one word for the given statement from the list.

Anion-cation, Nitrogenase, Ammonification, Magnesium, Nitrate, Chlorine, Soil, Mn, Auxin hormone, Potassium, Magnesium, Leghaemoglobin, Boron, α-ketoglutaric acid

Q.5 The process of conversion of nitrogen to ammonia is termed as _____.

Q.6 Hydroponics is growing plants in the complete absence of _____.

Q.7 Nitrogen is mainly absorbed in the form of ___.

Q.8 Plants with zinc deficiency show reduced biosynthesis of _____.

Q.9 Yellowish edges appear in leaves due to deficiency in ___.

Q.10 Complete the equation for reductive amination

$$\text{\_\_\_\_\_} + NH_4^+ + NADPH \xrightarrow[\text{Dehydrogenase}]{\text{Glutamate}} \text{Glutamate} + H_2O + NADP$$

Q.11 ____ macronutrient helps in opening and closing of stomata.

Q.12 _____ element helps in maintaining turgidity of the cells.

Q.13 Potassium helps in maintaining the ____ balance in cells.

Q.14 ____ is required for binding of ribosome subunits during protein synthesis.

Q.15 _____ micronutrient is involved in pollen germination.

Q.16 _____ is responsible for determining solute concentration in cell along with Na^+ and K^+.

Q.17 ____ mineral toxicity results in reduction in uptake of Mg and Fe.

Q.18 ___ converts atmospheric nitrogen into ammonia.

Q.19 The pink pigment found in the root nodules of a legume is _____.

Q.20 Boron deficiency leads to stout axis.
[True / False]

Q.21 Every mineral element that is present in a cell is needed by the cell. **[True / False]**

Q.22 Nitrogen as a nutrient element, is highly immobile in the plants. **[True / False]**

Q.23 It is very easy to establish the essentiality of micronutrients because they are required only in trace quantities. **[True / False]**

SECTION - 3 (ENHANCE PROBLEM SOLVING SKILLS)

Choose one correct response for each question.

PART - 1 : ESSENTIAL MINERAL ELEMENTS

Q.24 The nutrient solution in flowering culture hydroponics –

(A) is constantly recycled using a pump.
(B) flows back into the loam soil in which the plant grows.
(C) drains into a bucket for disposal.
(D) None of the above

Q.25 Lack or low level of causes an inhibition of cell division.
(A) Ca, Mg, Cu, K (B) N, K, S, Mo
(C) N, K, Mg, S, Fe (D) Zn, Mo, Mn

Q.26 Mineral element required by plants in the greatest amount is –
(A) nitrogen (B) potassium
(C) phosphorus (D) zinc

Q.27 Select an incorrect match
(A) Mn - Photolysis of water
(B) Fe - Carbohydrate and water translocation
(C) S - Constitutent of coenzyme A
(D) Ca - Synthesis of middle lamella

Q.28 Which of the following is one of the component of ATP?
(A) Potassium (B) Phosphorus
(C) Magnesium (D) Manganese

Q.29 Who demonstrated the concept of hydroponics for the first time ?
(A) Hewitt (B) Julius Von Sachs
(C) Dalton (D) None of these

Q.30 All given statements are correct w.r.t. criteria of essentiality of minerals, except
(A) Element must be absolutely necessary for normal growth and reproduction.
(B) Element must be replaceable by another element.
(C) Absence of a specific element causes deficiency in the plant which is corrected only by adding the specific mineral in the soil.
(D) Element play a direct role in plant metabolism.

Q.31 Which of the following is not caused by the deficiency of minerals?
(A) Chlorosis (B) Etiolation
(C) Shortening of internodes (D) Necrosis

Q.32 Primary symptom of manganese toxicity is
(A) Appearance of Brown spots surrounded by chlorotic veins.
(B) Loss of apical dominance.
(C) Little leaf disease.
(D) Reclamation disease.

Q.33 What effect can be seen on the plant growth and reproduction in the absence of essential mineral element?
(A) Plants will complete their life cycle normally.
(B) Plants will not complete their life cycle.
(C) There will be no effect on the normal growth but reproduction in plants will suffer.
(D) Only growth will get effected not the reproduction.

Q.34 Which of the following elements play a major role in nitrogen metabolism by activating the enzyme, nitrogenase?
(A) Cu^{+2} (B) Zn^{+2}
(C) Mg^{+2} (D) Mn^{+2}

Q.35 Element required for germination of pollen grains is –
(A) Boron (B) Chlorine
(C) Copper (D) Iron

Q.36 In the hydroponic plant production technique, in order to obtain the optimum growth, nutrient solutions must be –
(A) poorly aerated (B) adequately aerated
(C) diluted (D) None of these

Q.37 Find odd one out w.r.t. micronutrients
(A) Mn (B) B
(C) Cu (D) Ca

Q.38 Which of the following is not a micronutrient?
(A) Molybdenum (B) Magnesium
(C) Zinc (D) Boron

Q.39 Mark the correct option (w.r.t. hydroponics)
(A) It can avoid problem of soil borne pathogens.
(B) It avoids problem of weeding.
(C) Out of season vegetables and flowers can be obtained.
(D) All of these

Q.40 Chlorosis is –
(A) loss of chlorophyll
(B) yellowing of leaves
(C) death of blant tissue
(D) blackening of the leaves

Q.41 Deficiency of which set of minerals first appear in older leaves?
(A) N, K, Mg (B) N, Mg, Ca
(C) S, B, Mg (D) Mg, Ca, Fe

Q.42 Premature leaf fall is a disease caused due to the deficiency of –
(A) phosphorus (B) nitrogen
(C) calcium (D) potassium

Q.43 Which of the given is not a beneficial element?
(A) Co (B) Na
(C) Si (D) Ni

Q.44 Which of the following elements can be considers as macronutrients for plants?
(A) Zinc (B) Boron
(C) Nickel (D) Phosphorus

PART - 2 : ABSORPTION OF ELEMENTS

Q.45 In the initial phase of minerals absorption ions are taken up –
(A) slowly (B) rapidly
(C) fluently (D) simultaneously

Q.46 Read the following statements carefully
(a) Maximum mineral absorption through zone of elongation.
(b) Initial uptake of minerals is slow, into the symplast.
(c) Uptake in inner space is rapid.
(A) All are correct.
(B) Only (a) is incorrect.
(C) (b) and (c) are incorrect.
(D) Only (c) is incorrect.

Q.47 Which of the following statements are correct about mineral absorption in plants?
(A) In the initial phase, ions are taken up into the outer space of cells, the apoplast. It is a passive process.
(B) In the final phase, ions are taken slowly into the inner space, the symplast of cells and it is an active process.
(C) Passive movement of the ions into the apoplast occurs through ion channels, transmembrane proteins, which acts as selective pores.
(D) All of the above

Q.48 For the uptake of ions in the second phase of absorption of minerals, the pathway followed is called –
(A) passive uptake (B) active uptake
(C) neutral (D) None of these

Q.49 In the final phase of mineral absorption, ions are taken up into the space of cells.
(A) outer (B) inner
(C) extra inner membrane (D) None of these

Q.50 Essential ions are absorbed in different amounts by –
(A) root hairs (B) shoots
(C) phloem (D) None of these

PART - 3 : METABOLISM

Q.51 Free living nitrogen fixing bacteria are –
(A) *Bacillus polymixa* (B) *Rhodoseudomonas*
(C) *E. coli* (D) *Anabaena*

Q.52 Find a correct set of requirements to fix a molecule of atmospheric nitrogen (N_2)
(A) $8e^-$, $8H^+$, 8 ATP (B) $16e^-$, $16H^+$, 16 ATP
(C) $8e^-$, $8H^+$, 16ATP (D) $16e^-$, $16H^+$, 8 ATP

Q.53 Leghaemoglobin is important because it –
(A) transports oxygen to the root nodule.
(B) acts as an oxygen scavenger.
(C) provides energy to the nitrogen fixing bacterium.
(D) acts as a catalyst in transamination.

Q.54 Read the following statements carefully (w.r.t. symbiotic nitrogen fixation)
(a) Auxins are secreted by plants and cytokinins by bacteria when bacteria enter cortical region.
(b) Globin part of leghaemoglobin is formed by bacterial genome.
(c) Plant provides the ATP required for N_2 fixation.
(A) All are correct
(B) Only (b) is correct
(C) (a) & (c) are correct
(D) (a) & (b) are incorrect

Q.55 Which of the following is a limiting nutrient for both natural and agricultural ecosystems?
(A) Nitrogen oxides (B) Nitrogen
(C) Ammonia (D) Hydrogen

Q.56 All given statements are correct w.r.t. fate of ammonia, except
(A) Glutamine and asparagine are two most important amides in plants.
(B) α-Ketoglutaric acid provides carbon skeleton for the process of reductive amination process.
(C) Amides are transported through sieve tubes.
(D) Glutamic acid is the main amino acid that provides NH_2 group during transamination process.

Q.57 Name the fungus that helps in N_2-fixation –
(A) *Rhizopus* (B) *Albugo*
(C) *Puccinia* (D) *Pullularia*

Q.58 Enzyme nitrogenase is
(A) A Cu-Fe protein
(B) Found in prokaryotes only
(C) An O_2 requiring enzyme
(D) Essential to convert NH_3 to N_2

Q.59 *Anabaena*, which is extensively used in rice cultivation, forms symbiotic association with –
(A) *Cycas* roots (B) *Azolla*
(C) *Anthoceros* (D) *Alnus*

Q.60 *Nitrosomonas, Nitrococcus* and *Aspergillus flavus* are involved in the process of
(A) Ammonification (B) Nitrate assimilation
(C) Nitrification (D) Denitrification

Q.61 Which of the following shows the deficiency symptoms of nitrogen in plants?
(A) Delaying of flowering
(B) Increases protein synthesis
(C) Inhibition of chloroplast formation
(D) Dormancy of lateral buds

EXERCISE - 2 (LEVEL-2)

Choose one correct response for each question.

Q.1 Group of elements is not essential for a normal plant
(A) K, Ca, Mg (B) Fe, Zn, Mn, B
(C) Pb, I, Na (D) Mg, Fe, Mo

Q.2 Hydroponics is a technique in which plants are grown
(A) Green house
(B) Water saturated sand
(C) Balanced nutrient solution
(D) Purified distilled water

Q.3 For chlorophyll formation a plant needs :
(A) Fe, Ca & light (B) Fe, Mg & Light
(C) Ca, K & light (D) Mg & Cu

Q.4 The amino acid having S in its composition is
(A) Cystine (B) Cysteine
(C) Methionine (D) All

Q.5 Which elements are considered as balancing elements :
(A) Ca & K (B) C & H
(C) N & S (D) Mg & Fe

Q.6 The group of mineral nutrients known as frame work elements :
(A) N, S, P (B) C, H, O
(C) Mg, Fe, Zn (D) Zn, Mn, Cu

Q.7 Which element essential stability of chromosome structure
(A) Zn (B) Ca
(C) Mo (D) Fe

Q.8 "Reclamation" and "Little leaf" disease, caused by deficiency of
(A) Zn and Mo (B) Cu and Zn
(C) Cu and B (D) Mn and Cu

Q.9 Which element is required in comparatively least quantity for the growth of plant –
(A) Zn (B) N
(C) P (D) Ca

Q.10 Which of the following essential element is not properly placed in the given category :
(A) Cu (B) Zn
(C) Mg (D) Mn

Q.11 Criteria for essentiality in mineral nutrition were shown firstly by –
(A) Arnon (B) Liebig
(C) Steward (D) Levitt

Q.12 Which mineral nutrients are called critical element for crops:
(A) N, P, K (B) C, H, O
(C) N, S, Mg (D) K, Ca, Fe

Q.13 The mineral nutrient mainly concerning with apical meristematic activity is –
(A) K (B) Ca
(C) N (D) S

Q.14 Little leaf disease is caused by
(A) Zn - deficiency (B) Cu - deficiency
(C) Mo - deficiency (D) Mn - deficiency

Q.15 Which of the following does NPK denote
(A) Nitrogen, Potassium, Kinetin
(B) Nitrogen, Protein, Kinetin
(C) Nitrogen, Protein, Potassium
(D) Nitrogen, Phosphorus, Potassium

Q.16 Plants absorb mineral salts from the soil solution through:
(A) A semipermeable membrane into the cytoplasm.
(B) Perforations at the apex of root hair cells.
(C) The cell wall which is semipermeable.
(D) None of these

Q.17 Mineral salts which are absorbed by the roots from the soil are in the form of :
(A) Very dilute solution
(B) Dilute solution
(C) Concentrated solution
(D) Very concen. solution

Q.18 By which method ions are absorbed by the plants
(A) Diffusion (B) DPD gradient
(C) Carriers proteins (D) Water potential

Q.19 Hydrophytes absorb salt and water by :
(A) Root and root hairs (B) Leaves and roots
(C) Roots and stem (D) General epidermis

Q.20 Nitrogen fixation in root nodules of *Alnus* is brought about by –
(A) *Aerorhizobium* (B) *Bradyrhizobium*
(C) *Clostridium* (D) *Frankia*

Q.21 Which is free ion present in a cell :
(A) P (B) K
(C) Fe (D) B

Q.22 Which one of the following statements is correct?
(A) Legumes fix nitrogen through the specialized bacteria that live in their roots.
(B) Legumes fix nitrogen independently of the specialized bacteria that live in their roots.
(C) Legumes fix nitrogen only through specialized bacteria that live in their leaves.
(D) Legumes are incapable of fixing nitrogen.

Q.23 Roots of which plant contains a red pigment which have affinity for oxygen?
(A) Carrot (B) Soyabean
(C) Mustard (D) Radish

Q.24 Carrier protein helped in –
(A) Active absorption of ions
(B) Passive ions absorption
(C) Water absorption
(D) Vaporization

Q.25 Active uptake of minerals depends upon :
(A) Active water absorption
(B) Transpiration
(C) Photorespiration
(D) Dephosphorylation

Q.26 When chlorophyll is burnt, which one obtained :
(A) Fe (B) Mg
(C) Ca (D) Mn

Q.27 Brown heart rot of beets is due to deficiency of
(A) B (B) P
(C) Mg (D) Mo

Q.28 Die back disease in citrus is due to deficiency of:
(A) Mo (B) B
(C) Cu (D) Zn

Q.29 The disease related with deficiency of molybdenum is:
(A) Whiptail disease of cauliflower
(B) Little leaf disease
(C) Reclamation disease of cereals
(D) Brown heart disease

Q.30 Protoplasmic elements are :
(A) C, H, O, P, N, S (B) C, H, O, Fe, N
(C) N, S, Fe, P, K (D) Fe, Mg, Ca, N, P

Q.31 Which element is not considered as macronutrient
(A) Mg (B) Ca
(C) Mn (D) P

Q.32 The element which cannot be placed along with micro nutrients :
(A) Mn (B) Mo
(C) Cu (D) Ca

Q.33 Which element related with Khaira disease, of Paddy & auxin synthesis –
(A) Fe (B) Zn
(C) B (D) Cu

Q.34 Generally plants absorbed N_2 in the form of –
(A) NO_2^- (B) NO_3^-
(C) $N \equiv N$ (D) HNO_2

Q.35 Enzyme involved in nitrogen fixation is
(A) Nitrogenase (B) Nitroreductase
(C) Transferase (D) Transaminase

Q.36 Which is essential for N_2 metabolism :
(A) B (B) Mo
(C) Cu (D) Mg

Q.37 The major portion of the dry weight of plants comprises of –
(A) Nitrogen, phosphorus and potassium
(B) Calcium, magnesium and sulphur
(C) Carbon, nitrogen and hydrogen
(D) Carbon, hydrogen and oxygen

Q.38 Which one of the following mineral elements plays an important role in biological nitrogen fixation –
(A) Copper (B) Manganese
(C) Zinc (D) Molybdenum

Q.39 A free living nitrogen-fixing cyanobacterium which can also form symbiotic association with the water fern *Azolla* is
(A) *Tolypothrix* (B) *Chlorella*
(C) *Nostoc* (D) *Anabaena*

Q.40 The deficiencies of micronutrients, not only affects 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:
(A) Cu, Mn, Fe (B) Co, Ni, Mo
(C) Mn, Co, Ca (D) Ca, K, Na

Q.41 Which of the following elements is considered as beneficial elements in higher plants?
(A) Sodium and iron
(B) Silicon and potassium
(C) Cobalt and selenium
(D) All of these

Q.42 Which of the following is true regarding manganese toxicity in plants?
(A) Induction deficiencies of iron, magnesium and calcium.
(B) Appearance of brown spots surrounded by chlorotic veins.
(C) Inhibition of Ca^{2+} ions translocation in the shoot apex.
(D) All of the above

Q.43 Name the minerals responsible for maintaining cation-anion balance in the plant cells.
(A) K^+ and Fe^{+3} (B) Cl^- and K^+
(C) Ca^{+2} and Mg^{+2} (D) Cl^- and Mg^{+2}

Q.44 The structure present in *Cyanobacteria* (BGA) that helps in nitrogen fixation is
(A) homocyst (B) holostrum
(C) holotrema (D) heterocyst

Q.45 Which of the following reaction shows nitro flxation?
(A) $2NH_4 + 2O_2 + 8e^- \rightarrow N_2 + 4H_2O$
(B) $2NH_3 \rightarrow N_2 + 3H_2$
(C) $N_2 + 3H_2 \rightarrow 2NH_3$
(D) $2N_2$ + Glucose $\rightarrow$ 2 Amino acids

Q.46 Nitrogen is required mainly by which of the following parts of the plants?
I. Meristematic tissues.
II. Differentiating tissues.
III. Apical tissues.
IV. Metabolically active cell.
Choose the correct option.
(A) Only II (B) Only I
(C) I and II (D) I and IV

Q.47 The following reaction represents
α-ketoglutaric acid + NH_4^+ + NADPH $\xrightarrow[\text{dehydrogenose}]{\text{Glutamate}}$ Glutamate + H_2O + NADP
(A) Reductive amination (B) Transamination
(C) Amination (D) Nitrification

EXERCISE - 3 (LEVEL-3)

Choose one correct response for each question.

Q.1 All of the following statements concerning the Actinomycetous filamentous soil bacterium Frankia are correct except the Frankia –
(A) Can induce root nodules on many plant species.
(B) Cannot fix nitrogen in the free-living state.
(C) Like Rhizobium, it usually infects, its host plant through root hair deformation and stimulates cell proliferation in the host's cortex.
(D) Forms specialized vesicles in which the nitrogenase is protected from oxygen by a chemical barrier involving triterpene hopanoids.

Q.2 If by radiation all nitrogenase enzyme are inactivated, then there will be no –
(A) Fixation of nitrogen in legumes.
(B) Fixation of atmospheric nitrogen.
(C) Conversion from nitrate to nitrite in legumes.
(D) Conversion from ammonium to nitrate in soil.

Q.3 Farmers in a particular region were concerned that pre-mature yellowing of leaves of a pulse crop might cause decrease in the yield. Which treatment could be most beneficial to obtain maximum seed yield –
(A) Removal of all yellow leaves and spraying the remaining green leaves with 2,4,5-trichlorophenoxy acetic acid.

(B) Application of iron and magnesium to promote synthesis of chlorophyll.
(C) Frequent irrigation of the crop.
(D) Treatment of the plants with cytokinins alongwith a small dose of nitrogenous fertilizer.

Q.4 Sulphur is an important nutrient for optimum growth and productivity in –
(A) Fibre crops (B) seed crops
(C) Pulse crops (D) Cereals

Q.5 A plant requires magnesium for –
(A) Cell wall development
(B) Holding cells together
(C) Protein synthesis
(D) Chlorophyll synthesis

Q.6 Which of the following is a flowering plant with nodules containing filamentous nitrogen-fixing microorganism ?
(A) *Cicer arietinum*
(B) *Casuarina equisetifolia*
(C) *Crotalaria juncea*
(D) *Cycas revoluta*

Q.7 About 98 percent of the mass of every living organism is composed of just six elements including carbon, hydrogen, nitrogen, oxygen and
(A) Calcium and phosphorus
(B) Phosphorus &sulphur
(C) Sulphur and magnesium
(D) Magnesium & sodium

Q.8 Which one of the following elements is not an essential micronutrient for plant growth –
(A) Ca (B) Mn
(C) Zn (D) Cu

Q.9 Stomata of CAM plants –
(A) Are always open.
(B) Open during the day & close at night.
(C) Open during the night & close during the day.
(D) Never open.

Q.10 Stomata of a plant open due to –
(A) Influx of potassium ions.
(B) Efflux of potassium ions.
(C) Influx of hydrogen ions.
(D) Influx of calcium ions.

Q.11 Plants deficient of element zinc, show its effect on the biosynthesis of plant growth hormone
(A) Auxin (B) Cytokinin
(C) Ethylene (D) Abscisic acid

Q.12 One of the free-living anaerobic nitrogen-fixer is
(A) *Azotobacter* (B) *Beijernickia*
(C) *Rhodospirillum* (D) *Rhizobium*

Q.13 Gray spots of Oat are caused by deficiency of :
(A) Cu (B) Zn
(C) Mn (D) Fe

Q.14 Most abundant element present in the plants is
(A) Iron (B) Carbon
(C) Nitrogen (D) Manganese

Note (Q.15-Q.17) :
(A) S-1 is True, S-2 is True, S-2 is a correct explanation for S-1
(B) S-1 is True, S-2 is True ; S-2 is NOT a correct explanation for S-1
(C) S-1 is True, S-2 is False
(D) S-1 is False, S-2 is False

Q.15 **Statement 1 :** Use of fertilizers greatly enhances crop productivity.
Statement 2 : Irrigation is very important in increasing crop productivity.

Q.16 **Statement 1 :** Iron takes part in electron transport system of mitochondria.
Statement 2 : Iron has no role in chlorophyll synthesis.

Q.17 **Statement 1 :** Salt resistant plants survive in saline habitats by maintaining low internal Na^+ levels.
Statement 2 : Salt resistant plants get rid of excess Na^+ by ATP energy based antiporter.

Q.18 Mark the statements as true/false by choosing the correct option from the set (I-IV) given below.
I. Magnesium is a constituent of chlorophyll & helps to maintain the ribosome structure.
II. Calcium is needed during the formation of mitotic spindle.
III. Magnesium is essential for the photolysis of water.
IV. Zinc helps in sugar translocation.

(A) I-True, II-True, III-False, IV-False
(B) I-False, II-True, III-False, IV-True
(C) I-True, II-False, III-True, IV-False
(D) I-False, II-False, III-True, IV-True

Q.19 A small aquatic plant was put in each of the petri dishes X, Y and Z, containing different culture solutions, After six weeks, the plants in dish-had the same number of leaves as it had previously and they all were small and yellowish. Plant in dish-Y had more leaves of normal size and dark green colour. Plants in dish-Z had more leaves of normal size but very pale. Identify the missing elements in all the three petridish (X, Y, Z)?
(A) X-Magnesium, Y-Phosphorus, Z-Nitrogen.
(B) X-Phosphorus, Y-Magnesium, Z-Nitrogen.
(C) X-Phosphorus, Y-Nitrogen, Z-Magnesium.
(D) X-Magnesium, Y-Nitrogen, Z-Phosphorus.

Q.20 Select the incorrect statement.
(A) *Anabaena* and *Nostoc* are not capable of fixing nitrogen in free living state.
(B) Phosphorus is a constituent of cell membranes, certain nucleic acid and cell proteins.
(C) Root nodule forming nitrogen fixers live as aerobes under free-living conditions.
(D) *Nitrosomonas* and *Nitrobacter* are chemoautotrophs.

Q.21 The common nitrogen-fixer in paddy fields is
(A) *Frankia* (B) *Rhizobium*
(C) *Azospirillum* (D) *Oscillatoria*

Q.22 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?
(A) Leghaemoglobin scavenges oxygen and is pinkish in colour.
(B) Nodules act as sites for nitrogen fixation.
(C) The enzyme nitrogenase catalyses the conversion of atmospheric N_2 to NH_3.
(D) Nitrogenase is insensitive to oxygen.

Q.23 Tryptophan synthesis, carboxylase activity and little leaf of plants are all associated with –
(A) Zn (B) B
(C) Ca (D) Cu

EXERCISE - 4 (PREVIOUS YEARS AIPMT/NEET EXAM QUESTIONS)

Choose one correct response for each question.

Q.1 The first stable product of fixation of atmospheric nitrogen in leguminous plants is – **[NEET 2013]**
(A) Glutamate (B) NO_2^-
(C) Ammonia (D) NO_3^-

Q.2 Deficiency symptoms of nitrogen and potassium are visible first in **[AIPMT 2014]**
(A) Senescent leaves (B) Young leaves
(C) Roots (D) Buds

Q.3 Minerals known to be required in large amounts for plant growth include : **[AIPMT 2015]**
(A) Calcium,magnesium,manganese, copper.
(B) Potassium, phosphorus, selenium, boron.
(C) Magnesium, sulphur, iron, zinc.
(D) Phosphorus, potassium, sulphur, calcium.

Q.4 During biological nitrogen fixation, inactivation of nitrogenase by oxygen poisoning is prevented by **[RE-AIPMT 2015]**
(A) Xanthophyll (B) Carotene
(C) Cytochrome (D) Leghemoglobin

Q.5 In which of the following all three are macronutrients? **[NEET 2016 PHASE 1]**
(A) Boron, zinc, manganese
(B) Iron, copper, molybdenum
(C) Molybdenum, magnesium, manganese
(D) Nitrogen, calcium, phosphorus

Q.6 A system of rotating crops with legume or grass pasture to imporve soil structure and fertility is called – **[NEET 2016 PHASE 1]**
(A) Ley farming (B) Contour farming
(C) Strip farming (D) Shifting agriculture

Q.7 Which is essential for the growth of root tip? **[NEET 2016 PHASE 2]**
(A) Zn (B) Fe
(C) Ca (D) Mn

Q.8 Which of the following elements is responsible for maintaining turgor in cells? **[NEET 2018]**
(A) Potassium (B) Sodium
(C) Magnesium (D) Calcium

Q.9 In which of the following forms is iron absorbed by plants? **[NEET 2018]**
(A) Free element
(B) Ferrous
(C) Ferric
(D) Both ferric and ferrous

Q.10 *Thiobacillus* is a group of bacteria helpful in carrying out **[NEET 2019]**
(A) Nitrogen fixation
(B) Chemoautotrophic fixation
(C) Nitrification
(D) Denitrification

ANSWER KEY

EXERCISE-1 (SECTION-1&2)

(1) (A) **(2)** (D)
(3) (A) **(4)** (B)
(5) Ammonification **(6)** Soil
(7) Nitrate **(8)** Auxin hormone.
(9) Magnesium
(10) α-ketoglutaric acid **(11)** Potassium
(12) Potassium **(13)** Anion-cation
(14) Magnesium **(15)** Boron
(16) Chlorine **(17)** Mn
(18) Nitrogenase **(19)** Leghaemoglobin
(20) True **(21)** False
(22) False **(23)** True

EXERCISE - 1 [SECTION-3]																								
Q	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**
A	A	B	A	B	B	B	B	B	A	B	D	A	B	D	B	D	B	A	A	D	D	B	C	D	B
Q	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**												
A	B	A	A	C	B	C	B	C	D	B	B	C	A												

EXERCISE - 2																								
Q	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
A	C	C	B	D	A	B	B	B	A	C	A	A	B	A	D	A	A	C	D	D	B	A	B	A	D
Q	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**			
A	B	A	C	A	A	C	D	B	B	A	B	D	D	D	A	C	D	B	D	C	D	A			

EXERCISE - 3																							
Q	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
A	B	A	B	B	D	B	B	A	C	A	A	C	C	B	B	C	A	A	A	B	D	D	A

EXERCISE - 4										
Q	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
A	C	A	D	D	D	A	C	A	C	D

SOLUTIONS

EXERCISE-1

(1) (A) **(2)** (D)
(3) (A) **(4)** (B)
(5) Ammonification
(6) **Soil.** The technique of growing plants in a nutrient solution is known as hydroponics and it involves growing of plants in the complete absence of soil with defined minerals solution.
(7) Nitrate
(8) Auxin hormone.
(9) Magnesium.
(10) **α-ketoglutaric acid** + NH_4^+ + NADPH $\xrightarrow[\text{Dehydrogenase}]{\text{Glutamate}}$ Glutamate + H_2O + NADP
(11) Potassium **(12)** Potassium
(13) Anion-cation **(14)** Magnesium
(15) Boron **(16)** Chlorine
(17) Mn **(18)** Nitrogenase
(19) Leghaemoglobin **(20)** True
(21) **False.** All the mineral elements present in a cell are not needed by the cell. For example, plants growing near radioactive mining sites tend to accumulate large amounts of radioactive compounds. These compounds are not essential for the plants.
(22) **False.** Nitrogen as a nutrient element is highly mobile in plants. It can be mobilised from the old and mature parts of a plant to its younger parts.
(23) True **(24)** (A)
(25) (B) **(26)** (A)
(27) (B) **(28)** (B)
(29) **(B).** In 1860, Julius Von Sachs, a prominent German botanist, demonstrated for the first time that the plants could be grown to maturity in a defined nutrient solution in the complete absence of soil.
(30) (B)
(31) **(B).** Etiolation is the symptom developed in plants when they are grown in the dark. Examples includes, pale yellow or white colour due to lack of chlorophyll, long internodes, small and rudimentary leaves, poor development of lignified tissue.
(32) (A)
(33) **(B).** In the absence of essential mineral elements, plants do not complete their life cycle or set the seeds.
(34) **(D).** Mn^{+2} acts as an activator of nitrogenase during nitrogen fixation.
(35) (A)
(36) (B)
(37) (D)
(38) **(B).** The essential elements, which are required in very small amount by the plants are called micronutrient, e.g., Zn, Mn, B, Cu, Mo and Cl.
(39) (D)
(40) **(B).** Chlorosis is the loss of chlorophyll, which results in the yellowing of leaves
(41) (A)
(42) **(A).** Phosphorus is a constituent of nucleic acids, proteins, $NADP^+$, etc. Its deficiency causes chlorosis, necrosis and premature falling of the leaves and flowers.
(43) (D)
(44) **(D).** The macronutrients includes carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, calcium and magnesium.
(45) **(B).** In the initial phase, ions are taken up rapidly.
(46) (C)
(47) **(D).** Ions uptake takes place in two steps :
(i) **Initial phase :** Rapid uptake of ions into the 'outer free space' of cells, the apoplast. It is called passive uptake.
(ii) **Second phase :** Ions are driven up into the inner space, by the symplast of the cells.
(48) (B)
(49) **(B).** In the final phase, ions are taken up into the inner space of cells.
(50) **(A).** Essential ions are absorbed in different amounts with the need of roots hairs.
(51) **(A).** *Bacillus polymixa* is a free-living nitrogen fixing bacteria.
(52) (C)
(53) **(B).** Leghaemoglobin provides pinkish colour to the root nodules. The cells of the root nodules contains irregular polyhedral bacteria called bacteroids.

Leghaemoglobin is located between bacteroids and surrounding host membrane. Leghaemoglobin is an oxygen scavenger and protects the nitrogen fixing enzyme, nitrogenase.

(54) (C)
(55) (B)
(56) (C)
(57) **(D).** *Pullularia* helps in nitrogen fixation.
(58) (B)
(59) **(B).** *Anabaena* forms an association called symbiotic association with *Azolla*, which is extensively used in rice cultivation.
(60) (C)
(61) **(A).** Due to the deficiency of nitrogen, delaying of flowering appears.

EXERCISE-2

(1) (C) **(2)** (C)
(3) **(B).** For chlorophyll formation a plant needs Fe, Mg & Light
(4) (D) **(5)** (A)
(6) (B) **(7)** (B)
(8) **(B).** "Reclamation" and "Little leaf" disease, caused by deficiency of Cu and Zn.
(9) (A) **(10)** (C) **(11)** (A) **(12)** (A)
(13) (B) **(14)** (A) **(15)** (D) **(16)** (A)
(17) (A) **(18)** (C) **(19)** (D) **(20)** (D)
(21) (B) **(22)** (A) **(23)** (B) **(24)** (A)
(25) (D) **(26)** (B)
(27) **(A).** Boron deficiency is a common deficiency of the micronutrient boron in plants. It is the most widespread micronutrient deficiency around the world and causes large losses in crop production and crop quality.
(28) (C) **(29)** (A)
(30) **(A).** Generally the protoplasm consists of oxygen, carbon, hydrogen and nitrogen.
Approximately the oxygen is 62%, carbon 20%, hydrogen 10% and nitrogen 3%. The remainder of 5% part contains about thirty elements, of which calcium (Ca), iron (Fe), magnesium (Mg), chlorine (Cl), phosphorus (P), potassium (K), sulphur (S), etc., are important ones.
(31) (C)
(32) **(D).** Essential Micro-Nutrients
Boron (B) ; Chlorine (Cl) ; Copper (Cu) ; Iron (Fe)
Manganese (Mn) ; Zinc (Zn) ;
Molybdenum (Mo)
Nickel (Ni)
(33) **(B).** Zinc (Zn) deficiency is the most widespread micronutrient disorder in rice (Oryza sativa).
(34) (B) **(35)** (A)
(36) (B) **(37)** (D)
(38) **(D).** Molybdenum: is a structural component in the enzyme nitrate reductase that reduces nitrates to ammonia. This enzyme is found in all higher plants. Many plants reduce atmospheric nitrogen to ammonia via bacteria location in the roots. These bacteria use the enzyme nitrogenase, which also contains molybdenum. Without adequate levels the synthesis of proteins is blocked, plant growth may stunt and seeds may not form completely.
(39) (D)
(40) **(A).** Iron : is a component of many structural and enzyme proteins. It is essential for electron transport and chlorophyll biosynthesis. It is therefore required for photosynthesis and respiration .
Copper : is an integral component of several needed enzymes and other critical biological proteins . It is required for photosynthesis , respiration, pollen grain formation and in carbohydrate, nitrogen and lipid metabolism.
Manganese is required for respiration and both carbohydrate and lipid metabolism.
(41) (C)
(42) **(D).** The prominent symptoms of manganese toxicity is the appearance of brown spots surrounded by chlorotic veins.
It is important to know that manganese competes with iron and magnesium for its uptake by the plants and with magnesium for its binding with enzymes. Manganese also inhibits calcium translocation in shoot apex.
Therefore, excess of manganese may induce deficiencies of iron, magnesium and calcium.

(43) **(B). Functions of Cl^- :** It helps photolysis of water, maintenance of solute concentration and ionic balance.
Function of K : Potassium plays an important role in the opening and closing of stomata. These both can alter the osmotic potential of a cell.

(44) **(D).** Cyanobacteria or blue-green algae have the quality to fix atmospheric nitrogen. It is possible due to the presence of heterocysts.

(45) **(C).** During the conversion of nitrogen, cyanobacteria first converts nitrogen into ammonia and ammonium. Plants can use ammonia as a nitrogen source.

$$N_2 + 3H_2 \rightarrow 2NH_3$$

(46) **(D).** In plants, nitrogen is required by all the parts, particularly by the meristematic tissues and the metabolically active cells.

(47) **(A).** The organic acid-α-ketoglutaric acid, plays a key role in the synthesis of amino acid. The ammonia formed by nitrogen assimilation (i.e., reduction of nitrates), reacts with α-ketoglutaric acid to form an amino acid, i.e., glutamic acid.
In this process, α-ketoglutaric acid comes from Krebs cycle and hydrogen is donated by the coenzyme NADH or NADPH. The reaction occurs in the presence of enzyme glutamic dehydrogenase.

EXERCISE-3

(1)	(B)	**(2)**	(A)	**(3)**	(B)	**(4)**	(B)
(5)	(D)	**(6)**	(B)	**(7)**	(B)	**(8)**	(A)
(9)	(C)	**(10)**	(A)	**(11)**	(A)	**(12)**	(C)
(13)	(C)	**(14)**	(B)	**(15)**	(B)	**(16)**	(C)

(17) **(A).** Salt resistant plants survive in saline habitats by maintaining low internal Na^+ levels. They get rid of excess Na^+ ions by ATP energised anti porter.

(18) **(A).** Magnesium is present in tetrapyrrolic chlorophyll.
It is essential for continued growth of the apical meristem.
Calcium in small amounts is necessary for normal mitosis as it is important in chromatin or mitotic spindle organisation. Zinc is needed for the synthesis of auxin.

(19) **(A).** Magnesium (Mg), phosphorus (P) and nitrogen (N) will be used in the given culture.

(20) **(B).** Phosphorus is not a constituent of cell membrane, certain nucleic acids and cell proteins.

(21) (D) **(22)** (D) **(23)** (A)

EXERCISE-4

(1) **(C).** First stable product of fixation of atmospheric nitrogen in laeguminous plant is Ammonia.

$$\underset{\text{Nitrogen}}{N_2} \rightarrow \underset{\text{Dimide}}{N_2H_2} \rightarrow \underset{\text{Hydrazine}}{N_2H_4} \rightarrow \underset{\text{Ammonia}}{2NH_3}$$

(2) **(A).** Deficiency symptoms appear first in young leaves and young tissues in case of elements which are relatively immobile inside the plant e.g., Ca and S. For mobile elements like N and K, deficiency symptoms first appear in old and senescent leaves as the elements are mobilised from senescing regions for supply to young tissues.

(3) (D)

(4) **(D).** During Biological nitrogen fixation, inactivation of nitrogenase by oxygen poisoning is prevented by pink coloured oxygen scavenger pigment leghaemogolobin.

(5) (D)

(6) **(A).** The growing of granes or legumes in rotation with grain or tilled crops as a soil conservation measure.

(7) **(C).** Calcium is required by dividing and differentiating cells.

(8) **(A).** Potassium helps in maintaining turgidity of cells.

(9) **(C).** Iron is absorbed by plants in the form of ferric ions. Plants absorb iron in both form i.e. Fe^{++} and Fe^{+++}. (Preferably Fe^{++})

(10) **(D).** *Thiobacillus denitrificans* cause denitrification i.e., conversion of oxides of nitrogen to free N_2.