DAY FOURTEEN

Mineral Nutrition

Learning & Revision for the Day

- Methods to Study Mineral Requirement of Plants
- Classification of Mineral Elements
- Toxicity of Micronutrients
- Absorption of Mineral Elements
- Metabolism of Nitrogen

The supply and absorption of chemical compounds (organic and inorganic) needed for growth and metabolism is defined as **nutrition** and the chemical compounds required by an organism are termed as **nutrients**.

The inorganic elements required by the plant are present in the soil in the form of minerals and are known as **mineral elements** or **mineral nutrients**. Thus, the absorption, distribution and metabolism of various mineral elements by plant is called mineral nutrition.The first study on mineral nutrition was carried out by **van Helmont** in 1648.

Methods to Study Mineral Requirement of Plants

Requirement of different minerals by plants was determined by various scientists by using different experimental techniques. Some of them are given below:

Hydroponics In 1860, **Julius von Sachs** demonstrated for the first time that plant could be grown to maturity in a defined nutrient solution in complete absence of soil. The soilless production of plants is called hydroponics (term by Gericke in 1937). It is also known as soilless culture or solution culture.

Hydroponics or soilless culture helps to know

- The essentiality of mineral elements.
- The deficiency symptoms developed due to non-availability of particular nutrient.
- Toxic effects on plant when any element is present in excess.
- Possible interaction among different elements present in plants.
- The role of essential elements in the metabolism of plant.

Aeroponics is the technique of soilless culture in which roots of plants are suspended in the mist of oxygenated nutrient solution.

- **Sand culture**, in this sand is used as a rooting medium and nutrient solution is added to it.
- **Nutrient film technique** The nutrient solution drains through plant roots, through a channel. In this process, the plant roots do not have any substratum, but they are bathed regularly with nutrient solution.

Classification of Mineral Elements

On the basis of their essentiality or requirement for growth and metabolism, the minerals can be categorised into:

1. **Essential mineral elements** (17 in number) These elements have specific structural or physiological role. These are indispensable for plants to complete their life cycle, e.g. nitrogen, phosphorus, calcium, etc.
2. **Non-essential mineral elements** (other than 17 essential) These elements are required for the metabolic activities of some plants, but not all. Also, their absence does not produce any major deficiency symptoms in plants, e.g. cobalt, silicon, sodium, etc.

The term 'essential mineral element' was proposed by **Arnon** and **Stout in 1939**. On the basis of their quantitative requirements in plants, Hoagland divided essential elements into following two types

(i) **Micronutrients/Microelement/Trace-element** (equal to or less than 10 mole/kg of dry matter). These acts as cofactors or activators for the functioning of enzymes. These are eight in number, e.g. Zn, Mn, B, Cu, Mo, Cl, Ni and Fe.

(ii) **Macronutrients/Macroelements** (more than 10 mole/kg of dry matter) These are involved in the synthesis of organic molecules. These are nine in number, e.g. C, H, O, N, S, P, K, Mg and Ca. Of these macronutrients, carbon, hydrogen and oxygen are mainly obtained from CO_2 and H_2O, while the others are absorbed from the soil.

The essential mineral elements, their major form, function and deficiency symptoms are given in the table below

Macroelements their functions and deficiency symptoms

Elements	Obtained as	Functions	Deficiency symptoms
Carbon, hydrogen, oxygen (C, H, O)	Air and water	• Building blocks of the body. • Protoplasmic constituents. • H^+ governs pH. • Oxygen is the terminal electron acceptor in respiration. • Constituent of carbohydrates, proteins, lipids and nucleic acids.	• Normal growth cannot occur as they are building blocks of the body.
Nitrogen (N)	NO_3^-, NH_4^+ and NO_2^-	• Required for the formation or synthesis of amino acid, proteins, vitamins, nucleic acid, hormones, coenzymes, ATP and chlorophyll.	• Chlorosis appears first in older leaves. • Stunted growth due to decreased protein synthesis. • Premature leaf fall.
Sulphur (S)	SO_4^{2-}	• As a constituent of amino acids like cysteine and methionine, vitamins (thiamine and biotin), coenzyme-A and ferredoxin. • Increases the nodule formation in legumes, i.e. pulses. • Also a component of allyl sulphide in onion, garlic (responsible for smell) and sinigrin (mustard).	• Chlorosis more commonly appears first in young leaves. • Small chlorotic leaves in tea (tea yellow disease). • Reduced nodulation in legume.
Phosphorus (P)	Phosphate ions as $H_2PO_4^-$ or HPO_4^{2-}	• Required for the synthesis of nucleic acids, ATP, phospholipids, NAD and NADP. • Major functions are energy transfer, cell division, phosphorylation reactions. • Constituent of cell membrane.	• Stunted growth. • leaves dull green or with purple and red spot of anthocyanins. • Chlorosis (appears late) with necrosis first in older leaves. • Premature abscission (i.e. fall of leaf, fruit and flowers) • Red blot on leaves. • Delayed germination of seeds.

Elements	Obtained as	Functions	Deficiency symptoms
Potassium (K) (required in more abundant quantities in the meristematic tissues, buds leaves and root tips)	K^{+}	• Associated with anion-cation balance in the cell, K^{+} / Na^{+} pump in active transport. • Activates several enzymes (about 40). • Brings about opening and closing of stomata. • Essential for photosynthesis, respiration, chlorophyll synthesis, etc.	• Chlorosis followed by necrosis at the tip and margins of the leaves (appear first in older leaves). • Yellow leaf margins. • Inhibits protein synthesis and causes scorching of leaves.
Magnesium (Mg)	Mg^{2+}	• Involved in the synthesis of nucleic acid (DNA and RNA). • Helps to maintain the ribosome structure. • Constituent of the ring structure of chlorophyll. • Activator of enzymes involved in respiration, photosynthesis, fat and carbohydrate metabolism.	• Interveinal chlorosis of the older leaves. • Inhibition of growth. • Tips and margins of leaves turn upward. • Causes 'sand drown' disease in tobacco.
Calcium (Ca) (accumulates in older leaves and not remobilised)	Ca^{2+}	• Component of middle lamella of cell wall. • Controls cell permeability. • Needed during the formation of mitotic spindle. • Activator of enzymes. • Connected with chromosome formation and many aspects of metabolism. • Essential for root hair growth.	• Degeneration of meristems (especially root apex). • Chlorosis along the margins of young leaves. • Causes blossom end rot in tomato.

Microelements their functions and deficiency symptoms

Element	Obtained as	Major functions	Deficiency symptoms
Iron (Fe)	Fe^{3+} or Fe^{2+}	• As a structural component of porphyrin protein complexes (e.g. cytochromes, peroxidase, catalase, etc.) and ferredoxin, a member of ETS of chloroplast. Hence, it has a significant role in respiration and photosynthesis. • Activates catalase enzyme and also acts as cofactor of other enzymes (e.g. reductive enzymes). • Essential for chlorophyll synthesis.	• Leads to interveinal chlorosis, particularly in young leaves. • May be localised to single leaf or branch due to limited mobility. • Green netting of citrus.
Boron (B)	BO_3^{3-} and $B_4O_7^{2-}$	• Essential for meristematic activity and increases the uptake of water and calcium. • Essential for growth of pollen tube and formation of root nodules (in leguminous plants). • Also regulates active salt absorption and fat metabolism, hormone metabolism and photosynthesis. • Involved in carbohydrate translocation. • For uptake and utilisation of Ca^{2+}. • Necessary for increase in the fruit size.	• Death of root and stem apices. • Reduction in flower number and fruit size. • Causes heart rot of beets, stem crack of celery, brown heart of turnip, internal cork of apple, hollow stem of cauliflower and decreased nodulation in legumes.
Manganese (Mn)	Mn^{2+}	• Activates several enzymes like malic dehydrogenase, oxalosuccinic dehydrogenase (enzymes of Kreb's cycle), nitrate reductase and hydroxyl amine reductase. In the absence of Mn, cells prefer ammonia over nitrate. • Takes part in photolysis of water (splitting of H_2O to liberate O_2) during photosynthesis. • Essential for the synthesis of chlorophyll.	• Leads to leaf flecking or grey spots due to chlorosis and necrosis in interveinal zones. • Causes grey speck of oat, marsh spot disease in pea.

Elements	Obtained as	Functions	Deficiency symptoms
Zinc (Zn)	Zn^{2+}	• Essential for the synthesis of tryptophan which is precursor of IAA (Indole Acetic Acid–a plant growth substance). • Activates dehydrogenases and carboxylases. • Present in enzyme carbonic anhydrase. • Promotes synthesis of cytochromes.	• Reduction in internode length, rossette type growth. • Plants become dwarf with mottled and yellowish leaves. • Causes whiptip of maize, khaira disease of rice, sickle leaf of coca.
Copper (Cu)	Cu^{2+}	• Component of plastocyanin and cytochrome oxidase enzymes. • Involved in ETS in photosynthesis. • Functions as an activator of several enzymes. • Required for the synthesis of enzymes necessary for synthesis of ascorbic acid (vitamin-C).	• Leads to chlorosis and wilting of leaf margins. • Necrosis at the tip of young leaves and margins. • In citrus, causes die back diseases. • In cereals and legumes, it causes reclamation disease. • Causes exanthema disease, in which bark splits up at places to exude gum or resin.
Chlorine (Cl)	Cl^{-}	• It is required for photolysis of water during photosynthesis in photosystem-II. • With Na^{+} and K^{+}, it helps in determining solute concentration and anion-cation balance in the cells. • It increases water volume inside the cell and also regulates carbohydrate metabolism.	• Leads to wilted leaves which later become chlorotic and finally attain a bronze colour. • Roots become stunted or thickened and club-shaped and fruiting is reduced. • Photosynthesis is also inhibited. • Swollen root tips. • Flower abscission.
Nickel (Ni)	Ni^{2+}	• Metabolism of urea and ureides. • Helps in germination and early seedling growth of jack bean seed.	• Leaf tip necrosis.
Molybdenum (Mo)	MO_4^{2-}	• Aids in nitrogen fixation, as it is an activator of nitrate reductase. • It is required for the synthesis of ascorbic acid. • It acts as an activator of some dehydrogenases and phosphatases. • Components of nitrogenase, nitrate reductase and activator of dehydrogenase.	• Mottling and chlorosis first in older leaves and then in younger leaves. • May lead to abscission of flowers inhibition of fruit formation. • Causes whiptail disease of cauliflower (leaves become flaccid and brown).

Toxicity of Micronutrients

- Any mineral ion concentration in tissues that reduces the dry weight of tissues by about 10% is considered toxic. Such critical concentration varies widely among different micronutrients.
- The moderate decrease of micronutrients causes deficiency symptoms and a moderate increase causes toxicity. Toxicity level for any element varies for different plants.
  For example, excess of manganese may induce the deficiency of iron, magnesium and calcium. Thus, the manganese toxicity actually causes the deficiency symptoms of iron, magnesium and calcium.

Absorption of Mineral Elements

- Essential elements become available to the roots due to the weathering of rocks.
- These processes enrich the soil with dissolved ions and inorganic salts. Soil not only supplies minerals, but also harbours nitrogen-fixing bacteria and other microbes.
- It holds water and supplies air to the roots thus, acts as a matrix that stabilises the plant.
- The deficiency of essential minerals in soil can be restored by applying **fertilisers** and **manures**, for the better crop yield.
- Mineral salts are translocated through xylem along with the ascending stream of water, which is pulled up through the plant by transpirational pull.

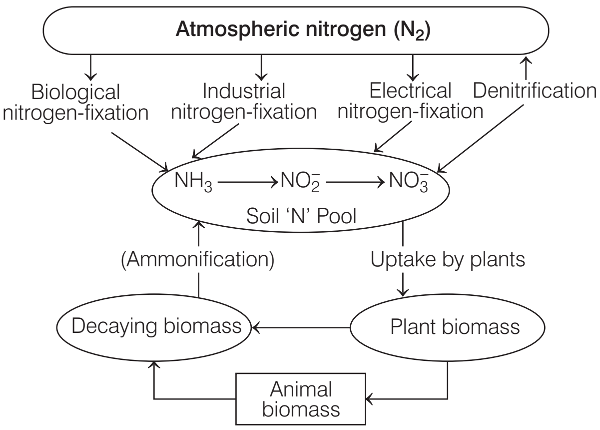
- The analysis of xylem sap shows the presence of mineral salts in it.
- The initial rapid uptake of ions into the 'free space' or 'outer space' of cells, i.e. the apoplast is passive. In the second phase of uptake, the ions are taken in slowly into the 'inner space', i.e. the symplast of the cells.
- The passive movement of ions into the apoplast usually occurs through ion-channels, the transmembrane proteins that function as selective pores.
- The entry or exit of ions to and from the symplast requires the expenditure of metabolic energy (ATP) which is an active process.
- Symplast includes translocation through plasmodesmata.
- The movement of ions is usually called **flux**. The inward movement into cells is **influx** and the outward movement is **efflux**.

Metabolism of Nitrogen

- Apart from carbon, hydrogen and oxygen, nitrogen is the most prevalent element in living organisms.
- Atmospheric nitrogen exists in molecular form as two nitrogen atoms are joined by a very strong triple covalent bond ($N \equiv N$).
- The molecular nitrogen is a highly inert gas and it is difficult for most of the living organisms, including the higher plants, to obtain it directly for their use.
- For this purpose, it must be fixed, i.e. combined with other elements such as carbon, hydrogen and oxygen to form compounds (such as nitrates, nitrites, ammonium salts, etc.) before it is absorbed and utilised by the plants.
- The microbial decomposition of organic remains of dead plants and animals supplies the nitrogen to soil in form of nitrate and ammonium ions. Microbes also converts atmospheric nitrogen into usable forms, this process is called nitrogen-fixation.

Nitrogen Cycle

- Nitrogen is the most prevalent element for living organisms. In soil, it is available to the roots of higher plants mostly as NO_3^- (nitrate), NH_4^+ (ammonium) and NO_2^- (nitrite) ions.
- The regular supply of nitrogen is maintained through the nitrogen cycle in nature.
- N_2 cycle can be conveniently discussed under the following steps:
  (i) N_2-fixation
  (ii) Ammonification
  (iii) Nitrification
  (iv) Denitrification



Nitrogen cycle

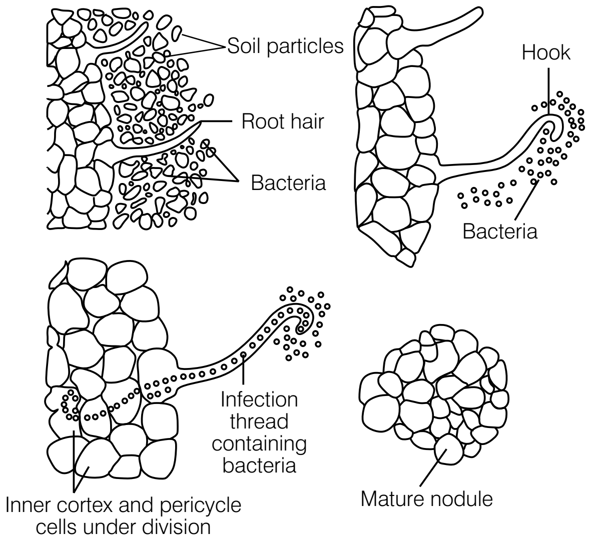
(i) Nitrogen (N_2) Fixation (Biological nitrogen-fixation)

- The conversion of atmospheric molecular nitrogen (N_2) into usable forms of nitrogen like nitrate, ammonia, amino acids, etc., is called **nitrogen fixation**.
- It may be abiological (due to lightning and thundering or in industries) or biological. The conversion of molecular nitrogen into inorganic nitrogenous compounds through bacteria and cyanobacteria (blue-green algae) is called **biological nitrogen fixation**. The organisms include both free-living and symbiotic forms.
  (a) **Free living nitrogen fixing bacteria**, e.g.
    - *Azotobacter*, *Beijerinckia* – Aerobic, saprotrophic
    - *Clostridium*, *Bacillus* – Anaerobic, saprotrophic
    - *Desulphovibrio* – Chemotrophic
    - *Rhodopseudomonas, Rhodospirillum, Chromatium* – Anaerobic, photoautotrophic
  (b) **Free-living nitrogen fixing cyanobacteria**, e.g. *Calothrix, Lyngbia, Aulosira, Cylindrospermum, Trichodesmium, Anabaena, Nostoc*.
  (c) **Symbiotic nitrogen fixing bacteria**, e.g. *Rhizobium, Frankia, Spirullum,* etc.
  (d) **Symbiotic nitrogen fixing cyanobacteria**, e.g. *Anabaena* and *Nostoc* species are common symbionts in lichens, *Azolla* in rice fields and coralloid root in *Cycas*.

Nodule Formation

- *Rhizobia* multiply and colonise the surroundings of roots and get attached to epidermal and root hair cells. The root hairs curl and the bacteria invade the root hair.
- An infection thread is produced carrying the bacteria into the cortex of the root, where they initiate the nodule formation.
- Then, the bacteria are released from the thread into the cells, which leads to the differentiation of specialised nitrogen-fixing cells.
- The nodule thus formed, establishes a direct vascular connection with the host for the exchange of nutrients.
- The nodule contains all the necessary biochemical components, such as the enzyme nitrogenase, an Mo-Fe

protein that is highly sensitive to oxygen called, **Leghaemoglobin** pigment (oxygen scavenger) protects nitrogenase enzyme from its oxidation by oxygen. It is a red pigment present in the peribacteroid space in the cytosol of nodule cells.



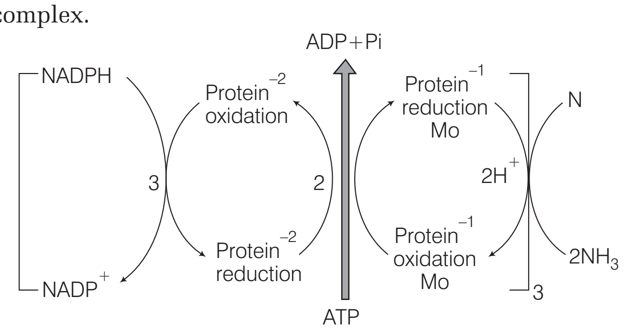
Development of root nodules in soybean

Mechanism of Biological N_2-Fixation

- The fixation of nitrogen in root nodules of legumes takes place in the presence of enzyme **nitrogenase**.
- The active nitrogenase complex contains protein-1 and protein-2 components in the ratio of 1 : 2.
- Fixation of nitrogen, i.e. its reduction to NH_3 is accomplished in three steps.
- In each step, two electrons (also 2 protons) are transferred from the reduced coenzyme NADPH to nitrogen.
- Di-imide and hydrazine are formed as intermediates. ATP, which comes through respiration provides energy during this reaction.

$$N \equiv N \xrightarrow[2H^+]{2e^-} \underset{\text{Di-imide}}{HN{=}NH} \xrightarrow[2H^+]{2e^-} \underset{\text{Hydrazine}}{H_2N - NH_2} \xrightarrow[2H^+]{2e^-} 2NH_3$$

- At each step, 2 electrons and 2 protons are transferred to nitrogen through the components of nitrogenase complex.



Mechanism of symbiotic N_2-fixation

The reaction catalysed by nitrogenase is summarised as follows

$$N_2 + 8e^- + 8H^+ + 16ATP \xrightarrow{\text{Dinitrogenase}} 2NH_3 + H_2 + 16ADP + 16P_i$$

- The ammonia synthesis by nitrogenase requires a very high input of energy (8ATP for each NH_3 produced) which is obtained from the respiration of the host cells.

NOTE Few plants are able to grow even in nitrogen deficient soils, without the association of nitrogen-fixing organisms.
These plants obtain or fulfil their nitrogen requirements by trapping insects and are called insectivorous plants, e.g. *Nepenthes*, *Drosera,* Venus fly trap, *Utricularia,* etc.

(ii) Ammonification

- Proteins and nucleic acids of the dead remains of plants, animals and excretory products of animals are degraded by microorganisms (e.g. *Bacillus ramosus, B. vulgaris, Clostridium*, *Actinomyces*, etc.), with the liberation of ammonia. This process is called **ammonification.**
- Proteins are first broken up into amino acids.
- The later are deaminated to form ammonia.
- Organic acids released during the process are used by microorganisms for their own metabolism.

$$\text{Protein} \xrightarrow{+H_2O} \underset{\text{Amino acid}}{R\text{—}NH_2} \xrightarrow{H_2O} \underset{\text{Organic acid}}{R\text{—}OH} + \underset{\text{Ammonia}}{NH_3}$$

- Ammonia changes from gaseous to ionic form in the soil and is utilised by the plants provided that pH of the soil is more than six and plants contain abundant organic acids for its uptake. Plants, e.g. *Begonia* and *Oxalis* can store ammonium ions.

(iii) Nitrification

- Ammonia thus produced by the degradation of manures and organic matter may not be available to plants because it readily leaches into the soil.
- It is converted into nitrate with the help of certain microorganisms.
- This conversion (oxidation) of ammonia to nitrate is called **nitrification**.
- It is performed in two steps, i.e. nitrite formation and nitrate formation.
- In the first step, ammonium ions are oxidised to nitrites. *Nitrosomonas* are the most important agents of oxidation of ammonia to nitrite in soil.
- Certain other bacteria are *Nitrosococcus, Nitrosolobus, Nitrosospira, Nocardia* and *Streptomyces.*
- In the second step, oxidation of nitrite to nitrate takes place and is dependent on the activities of bacteria belonging mainly to genera *Nitrobacter*.

- In addition, certain fungi, e.g. *Cephalosporium, Aspergillus* and *Penicillium* have been reported to carry out nitrification.

$$NH_4^+ + 3/2O_2 \xrightleftharpoons{\textit{Nitrosomonas}} NO_2^- + H_2O + H^+ \pm 84 \text{ kcal energy}$$

$$NO_2^- + 1/2\ O_2 \longrightarrow NO_3^- \pm 17.8 \text{ kcal energy}$$

Nitrate Assimilation in Plants

Nitrate cannot be utilised by plants as such. It is first reduced to ammonia before being incorporated into organic compounds. Reduction of nitrate occurs in following two steps

Step I Reduction of nitrate to nitrite is carried out by an inducible enzyme, nitrate reductase.

- The enzyme is a molybdo-flavo-protein.
- It requires a reduced coenzyme NADH or NADPH for its activity, which is brought in contact with nitrate by FAD or FMN.

$$NO_3 + NAD(P)H + H^+ \xrightarrow[\text{FAD/FMN}]{\text{Nitrate reductase}} \underset{\text{(Nitrite)}}{NO_2} + H_2O + NADP^+$$

Step II Reduction of nitrite is carried out by the enzyme nitrite reductase.

- The enzyme is a metalloflavoprotein, which contains copper and iron.
- It occurs inside the chloroplast in leaf cells and leucoplast of other cells. Nitrite reductase requires reducing power which is obtained from NADPH and NADH (NADPH in illuminated cells).
- Reduction process also requires ferredoxin, which occurs in green tissues of higher plants.
- It is presumed that in higher plants, either nitrite is translocated to leaf cells or some other electron donor (like FAD) operates in unilluminated cells. The product of nitrite reduction is ammonia.

$$2NO_2^- + 7NAD(P)H + 7H^+ \xrightarrow[\text{Ferredoxin}]{\text{Nitrite reductase}} 2NH_3 + 4H_2O + 7NAD(P)^+$$

Fate of Ammonia

- At physiological pH, the ammonia is protonated to form ammonium (NH_4^+) ion.
- This NH_4^+ ion is used to synthesise amino acids in plants by two main ways
  (a) In **reductive amination,** ammonia reacts with α-ketoglutaric acid and forms glutamic acid as indicated in the equation given below

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

  (b) **Transamination** involves the transfer of amino group from one amino acid to the keto group of a keto acid.
  - Glutamic acid is the main amino acid, from which the transfer of NH_2 (the amino group) takes place and other amino acids are formed through transamination.
  - The enzyme, transaminase catalyses all such reactions.
  - Aspargine and glutamine are the two most important amides, found in plants that form structural part of proteins.
  - Since, amides contain more nitrogen than the amino acids, they are transported to other parts of the plant *via* xylem vessels during transpiration.
  - The nodules of some plants (e.g. soybean) also export the fixed nitrogen as **ureides.** These compounds also have a particularly high nitrogen to carbon ratio.

(iv) Denitrification

- Some microorganisms use nitrate under anaerobic conditions and they reduce nitrates into gaseous compounds of N_2.
- The bacteria involved in this process are *Pseudomonas denitrificans, Thiobacillus denitrificans* and *Micrococcus denitrificans.*
- Some species of *Serratia, Bacillus* and *Achromobacter* are also involved.
- This process depletes important nutrients of soil, causes acidification of soil and helps to solubilise harmful metals present in soil.

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

DAY PRACTICE SESSION 1

FOUNDATION QUESTIONS EXERCISE

1 An essential element is one which
(a) improves plant growth
(b) is present in plant ash
(c) is available in soil
(d) is indispensable for growth and is irreplaceable

2 The framework elements of plants are
(a) magnesium, copper and iron
(b) copper, carbon and oxygen
(c) manganese, calcium and nitrogen
(d) carbon, hydrogen and oxygen

3 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 enhanced
(c) Essential element concentration below which plant remains in the vegetative phase
(d) None of the above

4 The minimal concentration of a macroelement per gram of dry matter in plants is
(a) 10 in mole/kg of dry matter
(b) 100 in mole/kg of dry matter
(c) 15 in mole/kg of dry matter
(d) 1000 in mole/kg of dry matter

5 Which one of the following is macronutrient?
(a) Ca (b) Mo (c) Mn (d) Zn

6 In which of the following, all three are macronutrients? ➞ NEET-II 2016
(a) Iron, copper, molybdenum
(b) Molybdenum, magnesium, manganese
(c) Nitrogen, nickel, phosphorus
(d) Boron, zinc, manganese

7 Essential micronutrients are also known as
(a) inorganic nutrients (b) trace elements
(c) radioisotope (d) organic nutrients

8 Microelements are those essential elements, which are required by the plants in concentration
(a) less than 10 mole/kg of dry matter
(b) less than 1 mole/ 10kg of dry matter
(c) more than 1 mole/kg of dry matter
(d) equal to 1 mole/kg of dry matter

9 Which one of the following is micronutrient?
(a) N (b) Ca (c) Cu (d) C

10 Nitrogen is absorbed by plants in the form of
(a) NO_3^- (b) NH_3 (c) NO_2^- (d) Both (a) and (c)

11 Complete suppression or delay in flowering occurs due to the deficiency of
(a) phosphorus (b) nitrogen
(c) calcium (d) iron

12 Attractive colour of apples may be induced by reducing the supply of
(a) Ca (b) N (c) K (d) B

13 Plant growth is stunted due to the deficiency of
(a) nitrogen and potassium (b) potassium and iron
(c) calcium and iron (d) All of these

14 Deficiency symptoms of nitrogen and potassium are visible first in ➞ CBSE-AIPMT 2014
(a) senescent leaves (b) young leaves
(c) roots (d) buds

15 Which one of the following helps in the absorption of phosphorus from soil by plants? ➞ CBSE-AIPMT 2011
(a) *Rhizobium* (b) *Frankia*
(c) *Anabaena* (d) *Glomus*

16 The most common ion found freely in the cell is
(a) phosphorus (b) potassium
(c) iron (d) sulphur

17 Sulphur is an important nutrient for optimum growth and productivity in
(a) pulse crops (b) cereals
(c) fibre crops (d) oilseed crops

18 Yellowing of tea leaves occurs due to the deficiency of
(a) Mo (b) S
(c) B (d) Mg

19 Biotin contains which one of the following elements?
(a) Cobalt (b) Sulphur
(c) Iron (d) Magnesium

20 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

21 Which one of the following elements is responsible for maintaining turgor in cells?
(a) Potassium (b) Sodium
(c) Magnesium (d) Calcium

22 A plant requires magnesium for
(a) holding cells together
(b) protein synthesis
(c) chlorophyll synthesis
(d) cell wall development

23 Manganese is required in
(a) nucleic acid synthesis
(b) plant cell wall formation
(c) photolysis of water during photosynthesis
(d) chlorophyll synthesis

24 Rapid deterioration of root and shoot occurs due to the deficiency of
(a) calcium (b) phosphorus
(c) carbon (d) nitrogen

25 Which is essential for the growth of root tip?
➞ NEET-II 2016
(a) Zn (b) Fe (c) Ca (d) Mn

26 Which one of the following elements in plants is not remobilised? ➞ CBSE-AIPMT 2011
(a) Calcium (b) Potassium
(c) Sulphur (d) Phosphorus

27 In which of the following forms is iron absorbed by plants? ➞ CBSE-AIPMT 2018
(a) Free element (b) Ferrous
(c) Ferric (d) Both (b) and (c)

28 The elements that take part in catalytic reactions are
(a) carbon, hydrogen and oxygen
(b) zinc, manganese and copper
(c) phosphorus, potassium and oxygen
(d) nitrogen, oxygen and zinc

29 Which of the following elements is absorbed by plants from soil directly?
(a) Carbon (b) Nitrogen (c) Boron (d) Hydrogen

30 Which element is useful for seed germination?
(a) B (b) Fe (c) Mg (d) Zn

31 The brown colour of leaves of cabbage, is due to the deficiency of
(a) boron (b) nitrogen (c) sulphur (d) calcium

32 Exanthema in citrus is caused due to the deficiency of
(a) Cu (b) Zn (c) Fe (d) Mn

33 The deficiency of molybdenum causes
(a) wilting of plant
(b) frequent leaf fall before senescence
(c) chlorosis in plant
(d) mottling and necrosis in plant

34 An element playing important role in nitogen-fixation is
➞ CBSE-AIPMT 2010
(a) molybdenum (b) copper
(c) manganese (d) zinc

35 The elements that cause toxic effect upon protoplasm are
(a) arsenic, copper and mercury
(b) carbon, hydrogen and oxygen
(c) arsenic, carbon and mercury
(d) copper, calcium and phosphorus

36 The deficiencies of micronutrients not only affect 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) Co, Ni, Mo (b) Ca, K, Na
(c) Mn, Co, Ca (d) Cu, Mn, Fe

37 Minerals absorbed by roots move to the leaf through
(a) xylem (b) phloem
(c) sieve tubes (d) None of these

38 Movement of ions or molecules against the electrochemical gradient is called
(a) diffusion (b) pinocytosis
(c) Brownian movement (d) active transport

39 The fact that the energy of metabolism is used in uptake of ions is demonstrated by
(a) increased ion uptake in the presence of O_2
(b) decreased ion uptake in the presence of O_2
(c) increased ion uptake in the presence of ATP
(d) increased ion uptake in the presence of NAD

40 Hydroponics is a system of growing plants in
(a) soilless cultures or solution cultures
(b) acidic soils
(c) soilless cultures with alkaline pH
(d) soilless cultures with acidic pH

41 Select the mismatched.

(a)	*Frankia*	–	*Alnus*
(b)	*Rhodospirillum*	–	Mycorrhiza
(c)	*Anabaena*	–	Nitrogen-fixer
(d)	*Rhizobium*	–	Alfa-alfa

42 Nitrogen-fixing bacterium is
(a) *Frankia* (b) *Acetobacter*
(c) *Mycoplasma* (d) *Chlamydia*

43 Nitrogen-fixation in root nodules of *Alnus* is brought about by ➞ CBSE-AIPMT 2009
(a) *Bradyrhizobium* (b) *Clostridium*
(c) *Frankia* (d) *Azorthizobium*

44 The common nitrogen-fixer in paddy field is
➞ CBSE-AIPMT 2010
(a) *Rhizobium* (b) *Azospirillum*
(c) *Oscillatoria* (d) *Frankia*

45 A nitrogen- fixing microbe associated with *Azolla* in rice field is
(a) *Spirulina* (b) *Anabaena*
(c) *Frankia* (d) *Tolypothrix*

46 The function of nitrogen- flxation in *Anabaena* (cyanobacterium) is performed by
(a) thylakoid (b) heterocyst
(c) phycocyanin (d) phycoerythrin

47 During biological nitrogen-fixation, inactivation of nitrogenase by oxygen poisoning is prevented by
➞ CBSE-AIPMT 2015
(a) leghaemoglobin (b) xanthophyll
(c) carotene (d) cytochrome

48 The first stable product of fixation of atmospheric nitrogen in leguminous plants is ➞ NEET 2013
(a) NO_2^- (b) ammonia
(c) NO_3^- (d) glutamate

49 Component of nitrogenase and nitrate reductase is

(a) N (b) Mo
(c) CO (d) No specific component

50 The pigment protein present in nodulated roots which is inhibited by *Rhizobium* is

(a) nitrate reductase (b) hydrogenase
(c) leghaemoglobin (d) plastocyanin

51 The function of leghaemoglobin during biological nitrogen-fixation in root nodules of legumes is to

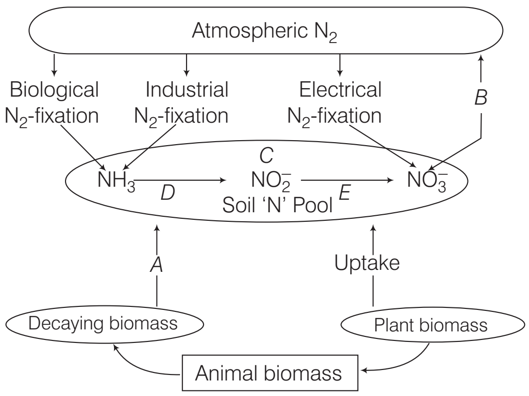
(a) convert atmospheric N_2 to NH_3
(b) convert ammonia to nitrite
(c) transport oxygen for activity of nitrogenase
(d) protect nitrogenase from oxygen

52 The insectivorous plants can grow well in the deficiency of

(a) nitrogen (b) oxygen
(c) carbon dioxide (d) hydrogen

53 Identify the labels in the given flow diagram which links the major nitrogen pools.

Choose the correct combination from the options given below.



(a) *A*–Nitrification, *B*–Ammonification, *C*–*Nitrobacter*, *D*–*Nitrosomonas*, *E*–Denitrification,
(b) *A*–Ammonification, *B*–Denitrification, *C*–Nitrification, *D*–*Nitrosomonas, E*–*Nitrobacter*
(c) *A*–Denitrification, *B*–*Nitrobacter, C*–Nitrification, *D*–*Nitrosomonas, E*–Ammonification
(d) *A*–*Nitrobacter, B*–Denitrification, *C*–*Nitrosomonas*, *D*–Ammonification, *E*– Nitrification

54 Match the following columns.

	Column I		Column II
A.	*Rhizobium*	1.	*Nostoc*
B.	*Azotobacter*	2.	Soilless plant production
C.	Cyanobacteria	3.	Nitrogen-fixing
D.	Hydroponics	4.	Root nodules

Codes

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

55 **Assertion** Root nodules are pinkish in colour internally.

Reason Pink colour is due to the presence of pigment leghaemoglobin.

(a) Both assertion and reason are true and reason is the correct explanation of assertion
(b) Both assertion and reason are true, but reason is not the correct explanation of assertion
(c) Assertion is true, but reason is false
(d) Both assertion and reason are flase

DAY PRACTICE SESSION 2

PROGRESSIVE QUESTIONS EXERCISE

1 Critical elements are

(a) N, P and S (b) N, S and K
(c) N, P and K (d) P, K and S

2 Aeroponics is also called as

(a) soilless cultivation of plants
(b) parthenocarpy
(c) vivipary
(d) phytotron

3 Which one of the following is not a micronutrient?

(a) Molybdenum (b) Magnesium
(c) Zinc (d) Boron

4 Passive absorption of minerals depends on

(a) temperature
(b) temperature and metabolic inhibitor
(c) metabolic inhibitor
(d) humidity

5 Which of the following is not caused by the deficiency of mineral nutrition?

(a) Necrosis
(b) Chlorosis
(c) Etiolation
(d) Shortening of internodes

6 Which one of the following elements is not an essential micronutrient for plant growth?

(a) Mn (b) Zn
(c) Cu (d) Ca

7 The plants grown in magnesium deficient but urea sprayed soil would show

(a) deep green foliage
(b) early flowering
(c) yellowing of leaves
(d) loss of pigments in petals

8 If by radiation, all nitrogenase enzymes 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

9 The function of leghaemoglobin in the root nodules of legumes is

(a) oxygen removal
(b) nodule differentiation
(c) expression of *nif* gene
(d) inhibition of nitrogenase activity

10 The ability of the Venus fly trap to capture the insects is due to

(a) chemical stimulation by the prey
(b) a passive process requiring no special ability on the part of the plant
(c) specialised 'muscle-like' cells
(d) rapid turgor pressure changes

11 Which of the following is a flowering plant with nodules containing filamentous nitrogen-fixing microorganism?

(a) *Casuarina equisetifolia*
(b) *Crotalaria juncea*
(c) *Cycas revoluta*
(d) *Cicer arietinum*

12 Who proved for the first time that the plants contain a large number of minerals and microelements?

(a) De Saussure (1840)
(b) Leibeg (1840)
(c) Glauber and Mayhow (1656)
(d) Arnon and Stout (1939)

13 Phosphorus and nitrogen ions generally get depleted in soil because they usually occur as

(a) neutral ions
(b) negatively charged ions
(c) positively charged ions
(d) both positively and negatively charged but disproportionate mixture

14 Nitrifying bacteria

(a) convert free nitrogen to nitrogen compounds
(b) convert proteins into ammonia
(c) reduce nitrates to free nitrogen
(d) oxidise ammonia to nitrates

15 What is the significance of ash in the study of mineral nutrition of plants?

(a) It tells that which minerals are present in the soil
(b) It informs about which element is essential and in which amount it is necessary for a particular plant
(c) It is of no practical significance
(d) It indicates that how much irrigation is needed for a plant

16 Why slight deficiency of phosphorus is considered to be useful to the plants against dessication?

(a) It induces greater mechanical tissues and higher root/shoot ratio
(b) It induces greater mechanical tissues and increase in the rate of photosynthesis
(c) It induces greater mechanical tissues and increase in the rate of respiration
(d) It induces greater mechanical tissues and increase in flowering

17 Is it possible to get a rough idea of the deficiency of an essential element in the soil without doing soil tests?

(a) Only by making a detailed analysis of the ash of a plant growing in it
(b) By noting the typical morphological symptoms of deficiency shown by plants growing in it
(c) By observing the physical texture of the soil
(d) By determining the dry weight of the plant

18 Farmers in a particular region were concerned that premature 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) Frequent irrigation of the crop
(b) Treatment of the plants with cytokinins along with a small dose of nitrogenous fertiliser
(c) Removal of all yellow leaves and sparying the remaining green leaves with 2, 4, 5-trichlorophenoxy acetic acid
(d) Application of iron and magnesium to promote synthesis of chlorophyll

19 Identify the option which correctly represents the gene responsible for the formation of nodules in leguminous plants.

(a) Nod gene of legume and *nif* gene of bacteria
(b) Nod gene of bacteria and *nif* gene of legume
(c) Nod gene of legume and *cry* gene of bacteria
(d) Nod gene of bacteria and *cry* gene of legume

20 Identify the correct statements from those given below.

I. Necrosis is the death of tissues, particularly in leaf, caused by deficiency of Ca, Mg, Cu and K.
II. Deficiency of N, S, Mo causes inhibition of cell division.
III. Mn^{2+} is toxic beyond 600 μg/g for soyabean.
IV. Ca^{2+} aids in nodule formation in legumes.

(a) I and IV (b) I and III
(c) I and II (d) III and IV

21 Match the following columns.

Column I		Column II	
A.	Reductive amination	1.	Destruction of chlorophyll
B.	Chlorosis	2.	16
C.	Essential elements	3.	Death of cells
D.	Necrosis	4.	Synthesis of amino acid
		5.	Growth of cells

Codes

	A	B	C	D		A	B	C	D
(a)	2	1	3	4	(b)	4	1	2	3
(c)	5	4	2	1	(d)	5	4	1	2

22 **Assertion** Deficiency of sulphur causes chlorosis in plants.

Reason Sulphur is a consituent of chlorophyll proteins and nucleic acids.

(a) Both Assertion and Reason are true, and Reason is the correct explanation of Assertion

(b) Both Assertion and Reason are true, but Reason is not the correct explanation of Assertion

(c) Assertion is true, but Reason is false

(d) Both Assertion and Reason are flase

ANSWERS

SESSION 1

1 (d)	**2** (d)	**3** (a)	**4** (a)	**5** (a)	**6** (c)	**7** (b)	**8** (a)	**9** (c)	**10** (d)
11 (b)	**12** (b)	**13** (a)	**14** (a)	**15** (d)	**16** (a)	**17** (a)	**18** (b)	**19** (b)	**20** (a)
21 (a)	**22** (c)	**23** (c)	**24** (a)	**25** (c)	**26** (a)	**27** (d)	**28** (b)	**29** (c)	**30** (a)
31 (a)	**32** (a)	**33** (d)	**34** (a)	**35** (a)	**36** (d)	**37** (a)	**38** (d)	**39** (c)	**40** (a)
41 (b)	**42** (a)	**43** (c)	**44** (b)	**45** (b)	**46** (b)	**47** (a)	**48** (b)	**49** (b)	**50** (d)
51 (d)	**52** (a)	**53** (b)	**54** (a)	**55** (a)					

SESSION 2

1 (c)	**2** (a)	**3** (b)	**4** (a)	**5** (c)	**6** (d)	**7** (c)	**8** (a)	**9** (a)	**10** (d)
11 (a)	**12** (b)	**13** (b)	**14** (d)	**15** (b)	**16** (a)	**17** (b)	**18** (d)	**19** (a)	**20** (b)
21 (b)	**22** (c)								