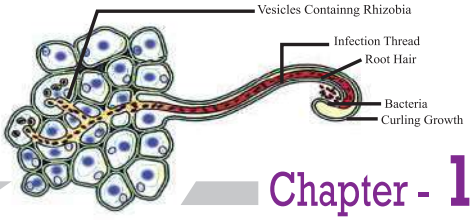


Chapter - 12

Mineral Nutrition

Based on functions :-

- Components of bio molecules of C, H, O, N
- components of energy related chemicals e.g. Mg, P
- Activator/Inhibitor of enzymes e.g. Zn^{2+}, Mo
- Alter osmotic potential of cell e.g. K, Na, Cl

Types of essential elements :-
(based on quantity)

Macronutrients :- Present in plant tissue in excess of 10 mole/kg of dry matter. e.g. C, H, O, N. P, S, K Ca, Mg

Micronutrients :-

Present in plant tissue less than 10 mole/kg of dry matter.

e.g. Fe, Mn, Cu, Mo, 2n, B, Cl, Ni

Criteria for Essentiality :-

- must be absolutely necessary for supporting normal growth and reproduction.
- requirement must be specific, not replaceable.
- must be directly involved in metabolism of the plant.

★ There are 17 essential elements.

MINERAL NUTRITION

Deficiency symptoms :-

Chlorosis:-Lossof chlorophyll, caused by deficiency of N, Mg, S. Fe, Mn, Zn & Mo

Necrosis -: Death of tissue caused by deficiency of Ca, Mg, Cu, K

Inhibition of cell division:- due to deficiency of N, K, S, Mo.

Delayed flowering : Caused Due to deficiency of N, K, S, Mo.

Toxicity of micro-nutrients : Moderate increase in micro-nutrient. Causes toxicity e.g Mn toxicity causes appearance of brown spots surrounded by chlorotic veins. Excess Mn induce deficiency of Fe, Mg, Ca.

Minerals are absorbed as ions :-

- Nitrogen as $No_3/NO^{2-}/NH^{4+}$
- Phosphorous as $H_2PO_4^-/HPO_4^{2-}$
- Potassium as K^+
- Calcium as Ca^{2+}
- Magnesium as Mg^{2+}
- Sulphur as SO_4^{2-}
- Iron as Fe^{3+}
- Manganese as Mn^{2+}
- Zinc as $2N^{2+}$
- Copper as Cu^{2+}
- Boron as Bo_3^{3-} or $B_4O_7^{2-}$
- Molybdenum as MoO_2^{2+}
- Chlorine as Cl^-

Points To Remember

Biological nitrogen fixation: Conversion of atmospheric nitrogen into organic compounds by living organisms.

Flux : The movement of ions is called flux. Influx is inward movement of ions into the cells and efflux is the outward movement of ions.

Necrosis : Death of tissues particularly leaf tissue due to deficiency of Ca, Mg, Cu, K.

Mineral Nutrition : Plants require mineral elements for their growth and development. The utilization of various absorbed ions by a plant for growth and development is called mineral nutrition of the plant.

Hydroponics : Soil-less culture of plants, where roots are immersed in nutrient solution (without soil) is called hydroponics. The result obtained from hydroponics may be used to determine deficiency symptoms of essential elements.

Passive Transport : Absorption of minerals with concentration gradient by the process of diffusion without the expense of metabolic energy.

Essential Elements There are 17 essential elements

In addition to the 17 essential elements, Na, Si, Co and Si are required by some higher plants.

Criteria for essentiality specificity, irreplaceable, direct involvement :

Role of Minerals Elements in Plants

MACRO NUTRIENTS

Element	Obtained as	Functions	Deficiency symptoms
Nitrogen (N)	Mainly as NO_3^- some as NO_2 or NH_4^+	Constituent of proteins, nucleic acids, vitamins and hormones.	Stunted growth Chlorosis, dormancy of apical causal buds.
Phosphorus (P)	Phosphate ions ($H_2PO_4^-$ or HPO_4^{2-})	Constituent of cell membrane. Required for the synthesis of nucleic acids, nucleotides, ATP NAD and NADP for phosphory-lation reactions.	Poor growth of plant. Leaves dull green, delay in seed germination purple or red spots on leaves, premature leaf fall.

Potasium (K)	K^+	Helps to maintain an anion-cation balance in cells. Involved in protein synthesis, in opening and closing of stomata; activation of enzymes; maintenance of turgidity of cells.	Stunted growth; yellow leaves of mottled appearance of leaves. Premature death.
Calcium (Ca)	Ca^{2+}	Required in formation of mitotic spindle; involved in normal functioning of cell membranes; activates certain enzymes; as calcium pectate in middle lamella of the cell wall.	Stunted growth, chlorosis of young leaves.
Magnesium (Mg)	Mg^{2+}	Activates enzymes in phosphate metabolism, constituent of chlorophyll; maintains ribosome structure.	Chlorosis between the leaf veins, necrosis, purple colours spots on older leaves.
Sulphur (S)	SO_4^{2-}	Constituent of two amino-acids-Cysteine and methionine and proteins, coenzymes, vitamins and ferredoxin.	Chlorosis of younger leaves, stunted growth

MICRO NUTRIENTS

Element	Obtained as	Functions	Deficiency symptoms
Iron (Fe)	Fe^{3+}	Constituent of Ferredoxin and cytochrome; needed for synthesis of chlorophyll.	Chlorosis of leaves
Manganese (Mn)	Mn^{2+}	Activates certain enzymes involved in photosynthesis, respiration and nitrogen metabolism.	Chlorosis, grey spots on leaves.

Zinc (Zn)	Zn^{2+}	Activates various enzymes like carboxylases. Required for synthesis of auxins.	Malformation of leaves
Copper (Cu)	Cu^{2+}	Activates certain enzymes. Essential for overall metabolism	Stunted growth, inter-veinal chlorosis in leaves. Necrosis of the tip of young leaves, drybark of shoot.
Boron (B)	BO_3^{3-}, $B_4O_7^{2-}$	Required for uptake of water and Ca, for membrane functioning, pollen germination, cell elongation carbohydrate translocation.	Death of stem and root apex, loss of apical dominance, abscission of flowers, small size of fruits
Molybdenum (Mo)	MoO_2^{2+} (molybdate ions)	Activates certain metabolism.	Nitrogen deficiency inter-veinal chlorosis retardation of growth
Chlorine (Cl)	Cl^-	Maintains solute concentration along with Na+ & K+; maintain anion-cation balance in cells; essential for oxygen evolution in photosynthesis.	Wilted leaves; stunted root growth and reduced fruiting.

Critical Concentration : The concentration of the essential element below which plant growth is retarted. The element is said to be deficient when present below the critical concentration.

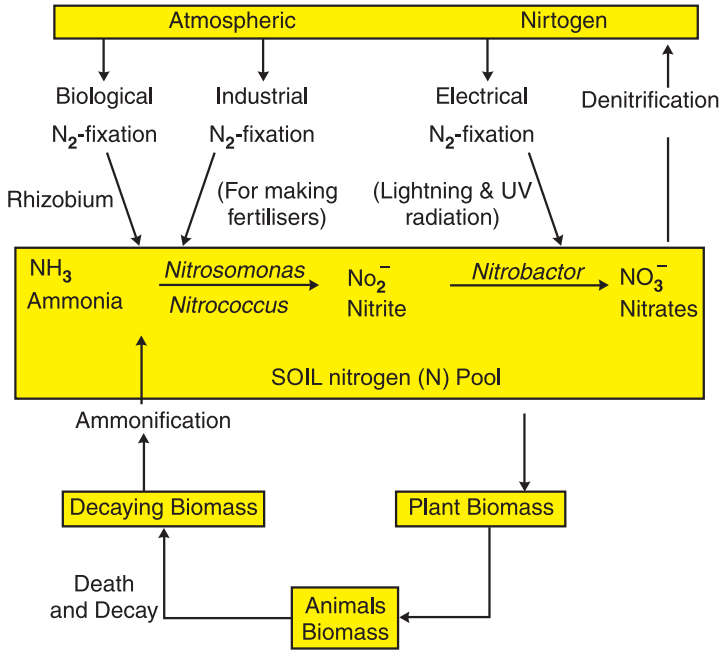
Deficiency symptoms : Chlorosis, necrosis, stunted growth, premature fall of leaves and buds and inhibition of cell division.

Toxicity of micronutrient : Any mineral ion concentration in tissues that reduces the dry weight of tissues by 10% is considered toxic. Toxicity of one element may lead to deficiency of other element since the former may inhibit the uptake of latter., e.g., Mn competes with Fe, Mg for uptake and also inhibits Ca translocation to shoot apex. Therefore Mn toxicity symptoms are actually same as deficiency symptoms of Fe, Mg and Ca.

Role of microbes in nitrogen cycle :

- *Rhizobium, Azotobacter, Rhodospirillum;* Fix atmospheric nitrogen
- *Nitrosomonas and/or Nitrococcus* : Conversion of ammonia to nitrite
- *Nitrobacter :* Conversion of nitrite into nitrate.
- *Pseudomonas* and *Thiobacillus* : reduce nitrate into nitrogen.

Nitrogen Cycle:



Nitrogen Cycle

Nitrogen fixation— (N_2) into ammonia.

Ammonification—The process of decomposition of organic nitrogen of plants and animals (proteins) into ammonia.

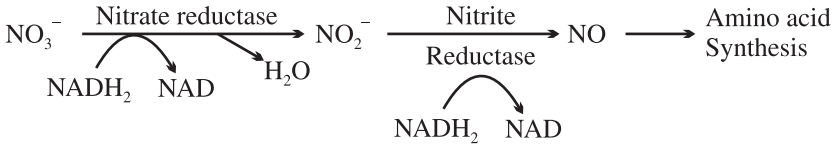
$$\text{Protien in Dead Plants and Animals} \xrightarrow[\text{Bacteria}]{\text{Ammonifying}} NH_3$$

Nitrification—The ammonia so formed may volatilise and re-enter the atmosphere, or some of the ammonia may be converted first into nitrite and then into nitrate by soil bacteria

$$2NH_3 + 3O_2 \xrightarrow{\textit{Nitrosomonas}} 2NO_2^- + 2H_2O + 2H^+$$

$$2NO_2^- + O_2 \xrightarrow{\textit{Nitrobactor}} 2NO_3^-$$

The Nitrate so formed can be easily absorbed by the plants and transported to leaves. In leaves, nitrate is reduced to ammonia to form amino-acids, because nitrate can not used by plants as such.



Denitrification—Process of reduction of the nitrate present in soil to nitrogen. It is carried out by bacteria like *Pseudomonas* and *Thiobacillus*.

Nitrogen fixation = $N_2 \rightarrow NH_3$

Biological Nitrogen Fixation—Reduction of nitrogen to ammonia by living organisms. Certain prokaryotes are able to fix nitrogen because of presence of 'nitrogenase' enzyme in them.

Nitrogen fixing microbes may be

(a) Free living—(i) Aerobic—*Azotobacter*

(ii) Anaerobic—*Rhodospirillum*

(b) Cyanobacteria—*Nostoc, Anabaena*

(c) Symbiotic—(i) With leguminous plants—*Rhizobium*

(ii) With non-leguminous plants—*Frankia*

Enzyme nitrogenase—The enzyme nitrogenase is Mo-Fe protein and catalysis the conversion of atmospheric nitrogen to ammonia (First stable product of nitrogen fixation)

Leg-hemoglobin—A pink colour pigment, similar to hemoglobin of vertebrates and functions as an oxygen scavenger and protects nitrogenase from oxygen.

Steps of nodule formation :

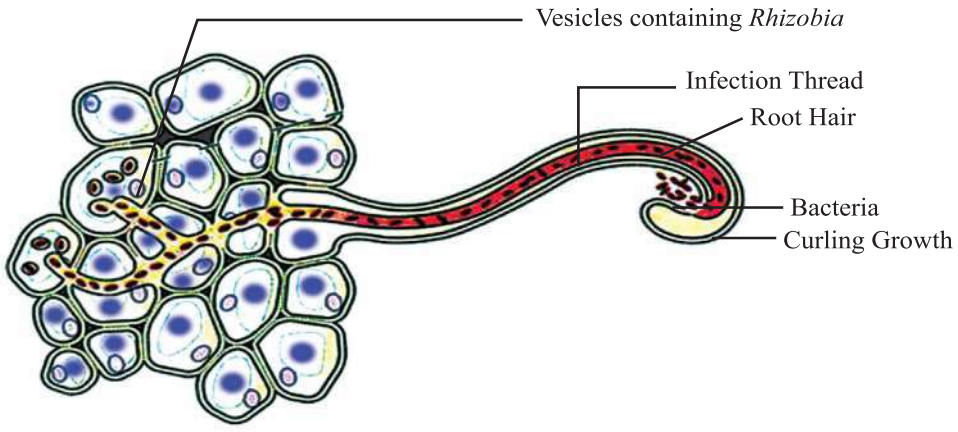
(a) *Rhizobium* bacteria present in soil contact a susceptible root hair.

(b) Infection of the root hair cause it to curve and deformed due to chemical secretion.

(c) An infection thread is produced carrying the bacteria into the cortex of the root.

(d) The bacteria get modified into rod-shaped bacteroids and cause inner cortical and pericycle cells to divide Plant produces cytokinin and auxin to stimulate cell division and enlarges to form nodules.

(e) Division and growth of cortical and pericycle cells lead to nodule formation.



Nodule Formation in Roots of Leguminous Plants

Mechanisms of N_2 fixation

It require 4 components—

(a) A strong reducing agent like $FADH_2$, $NADPH_2$

(b) Nitrogenase enzyme

(c) ATP (as energy service)

(d) Nitrogen gas molecule (as substrate)

$$N_2 + 8e^- + 8H^+ + 16\ ATP \longrightarrow 2NH_3 + H_2 + 16\ ADP + 16Pi$$

Fate of Ammonia :- At physiological pH, the ammonia is protonated to form NH^{4+}, which is quite toxic to plants and hence can not accumulate in them. It is used by plants in following ways–

(a) **Reductive amination :-** α – ketoglutaric acid + NH_4^+ + NADP

$$\xrightarrow[\text{Dehydrogenase}]{\text{glutamate}} \text{glutamate} + H_2O + NADP$$

(b) **Transamination :-** Transfer of amino group from one amino acid to the keto group of a keto acid to form amino acid with the help of enzyme transaminase.

(c) **Formation of Amides :-** The hydroxyl part of the acid is replaced by another amino radicle to form amides. e.g. asparagine and glutamine are formed from aspartic acid and glutamic acid.

Questions

(SRT) Select Response Type Question (1 mark each)

1. Name one symblotic nitrogen fixing bacteria.
   (a) *Rhizobium* (b) *E. coli*
   (c) *Pseudomones* (d) *Nitrosomonas*
2. .... & .... are examples of macronutriesnt.
   (a) S & Ca (b) Zn & Ca
   (c) Fe & B (d) C & A
3. Death of tissue, due to deficiency of Ca, Mg, Cu, K is....
   (a) Chlorosis (b) Wilting
   (c) Plasmolysis (d) Necrosis

CONSTRUCTED RESPONSE TYPE (CRT)

Very Short Answer Questions (1 mark each)

4. Which substance impart pink colour to the root nodule of a leguminous plant and also mention its role ?
5. What is the term used for mineral deficiency symptom in plants in which leaves become yellow in different pattern ?
6. Define hydroponics.
7. Give the name of an insectivorous angiosperm plant.
8. Give the name of one non-symbiotic nitrogen fixing prokaryote.
9. Name the green house gas produced in rice fields.
10. Name the element which is essential for the photolysis of water during photosynthesis.
11. Why do deficiency symptoms appear in older leaves first?

Short Answer Questions-I (2 marks each)

12. Differentiate between two types of absorption of minerals in plants from soil.

13. Name the following :
    (a) Bacteria which converts ammonia into nitrite.
    (b) Bacteria which oxidises nitrite into nitrate.
14. How does Leghemoglobin protect the enzyme nitrogenase ?
15. Name the enzyme found in root modules for N_2 fixation ? Name the pink coloured pigment required for its functioning.

Short Answer Questions-II (3 marks each)

16. Write the deficiency symptoms of the following three elements :
    (a) Phosphorus
    (b) Magnesium
    (c) Potassium
17. Describe the following three deficiency symptoms and co-relate them with concerned mineral deficiency :
    (a) Phosphorus
    (b) Magnesium
    (c) Potassium
18. Explain in brief the steps involved in biological nitrogen fixation.
19. Describe the two main processes of synthesis of amino acids from Ammonium ion (NH_4^+) in plants.
20. Define critical concentration, also mention four deficiency symptoms of nutrients in plants.
21. Write a short note on toxicity of micronutrient. Give an example which show toxicity of one element may lead to deficiency of other element.

Long Answers (5 marks each)

22. Describe all the steps of nitrogen cycle in nature.
23. Describe with diagrams how root nodules are formed in leguminous plants.
24. Explain adaptations in leguminous root nodules for N_2 fixation.

Answers

(SRT) Select Response Type Question (1 mark each)

1. (a) *Rhizobium* 2. (a) S & Ca
3. (d) Necrosis

CONSTRUCTED RESPONSE TYPE (CRT)

Very Short Answers (1 mark each)

4. Leghemoglobin. It is an oxygen scavenger, which protects the enzyme nitrogenase.
5. Necrosis.
6. The technique of growing plants in a nutrient solution without soil is called hydroponics.
7. *Nepenthes* (Pitcher plant)
8. *Azotobacter*
9. Methane (CH_4)
10. Calcium
11. It happens because the elements are mobilized to the younger parts of the plant from older leaves.

Short Answers-I (2 marks each)

12. Refer 'Points to Remember'.
13. (i) Nitrifying Bacteria—*Nitrosomonas*.
    (ii) Nitrifying Bacteria—*Nitrobacter*
14. Refer to page no. 203.
15. Enzyme-Nitrogenase
    Pink coloured pigment-Leghaemoglobin

Short Answers-II (3 marks each)

16. Refer to 'Points to Remember'.
17. Refer to 'Points to Remember'.

18. Refer to 'Points to Remember'.
19. Refer to 'Points to Remember' (Fate of Ammonia)
20. Refer to 'Points to Remember'.
21. Refer to 'Points to Remember'.

Long Answers (5 marks each)

22. Refer to 'Points to Remember'.
23. Refer to 'Points to Remember'.
24. Refer to 'Points to Remember'.

Assertion Reasoning (1 mark each)

The following question consists of 2 statements - Assertion (A) and Reason (R). Answer the question by selecting the appropriate option below :

(a) Both A and R are true and the reason is a correct explanation of the assertion

(b) The assertion is true but the reason is false

(c) Both the assertion and reason are false

(d) The assertion is false but the reason is true

25. **Assertion (A) :** Leguminous plants are grown alternatively with grain crops to replenish nitrogen in the soil.

    Reason (R) : Rhizobium is a symbiotic bacterium that can fix nitrogen while living in the roots of leguminous plants

26. **Assertion (A) :** If any mineral concentration in tissues that reduces the dry weight of tissues by about 10 percent is considered toxic.

    Reason (R) : It is difficult to analyse the symptoms of mineral toxicity

27. **Assertion (A) :** Calcium is required by meristematic and differentiating tissues.

    Reason (R) : It is essential fo rthe formation of the mitotic spindle and cell wall formation.

28. **Assertion (A) :** Hydroponic is a soil-less method to grow plants.

    Reason (R) : Commercial production of vegetable such as tomato, seedless cucumber and lettuce is done only with the help of hydroponics.

29. **Assertion (A) :** Influx of nutrients always occurs via facilitated diffusion.
Reason (R) : Energy is always required when there is an influx.

Solution

Assertion Reasoning

25. (a)
26. (b)
27. (a)
28. (b)
29. (d)

Source-based/Case-based/Passage-based/Integrated assessment questions (4 marks each)

Read the following and answer any four questions from (i) to (v) given below :

30. Soil is the reservoir of nutrients and the properties of soil depend upon the type of minerals present. In addition to essential mineral elements, there are some other minerals too that are grouped according to their biochemical behaviour and physiological functions in plants metabolism. Biogeochemical cycles replenish mineral nutrients in the soil. One of such important nutrients is nitrogen, plants cannot use nitrogen directly from the atmosphere. Many microbes play an important role in the absorption and recycling of nitrogen in an ecosystem. As plants use minerals, the soil becomes deficient in some nutrients. They are either added artificially or are enhanced using biofertilizers. These biofertilizers help plants to absorb certain minerals either symbiotically or non-symbiotically.

(i) Which of the following is a micronutrient?
   (a) Carbon
   (b) Nitrogen
   (c) Iron
   (d) Oxygen

(ii) What will happen if one of the micronutrients is available in the plant in excess?

(iii) In which of the following forms nitrogen is absorbed by the plants?
   (a) Nitrates and dimeric nitrogen
   (b) Nitrates and nitrites

(c) Nitrites and ammonia

(d) Dimeric nitrogen and ammonia

(iv) Name any two symbiotic nitrogen-fixing microbes.

(v) Deficiency of _____ leads to premature fall of leaves and they turn dark green in colour.

(a) Phosphorous

(b) Iron

(c) Nitrogen

(d) Potassium

Solution

Source-based/Case-based/Passage-based/Integrated assessment questions

(i) (c) Iron

(ii) It will cause mineral toxicity and will interfere with the metabolism of other micronutrients.

(iii) (b) Nitrates and nitrites

(iv) *Frankia, Rhizobium*

(v) Phosphorous