12. Mineral Nutrition

POINTS TO REMEMBER :

- **Autotrophs :** An organism that synthesize its required nutrients from simple and inorganic substances.
- **Heterotrophs :** An organism that cannot synthesize its own nutrients and depend on others.

Essential Mineral elements :

- More than sixty elements found in different plants.
- Some plant accumulates selenium, some other gold.

Criteria for Essentiality :

- Element absolutely necessary for normal growth and reproduction.
- In the absence of the element the plant can not complete their life cycle.
- Role of the element can not be replaced by any other elements.
- The element must be directly involved in the metabolism of plant.

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)

Four group of essential elements :

- As components of **biomolecules** and forms structural elements of cells (e.g. carbon, hydrogen, oxygen and nitrogen)
- As components of **energy-related** chemical compounds in plants. (magnesium in chlorophyll and phosphorous in ATP)
- Element that **activate** or **inhibit enzymes** (Mg^{2+}, Zn^{2+})
- Alter the **osmotic potential** of a cell. (K^+)

Role of macro and micro-nutrients :

Nitrogen :

- Absorbed in the form of NO_2^- or NH_4^+
- Required by meristematic tissue and metabolically active tissue.
- Constituent of proteins, nucleic acids, vitamins and hormones.

Phosphorus :

- Absorbed in the form of H_2PO_4- or HPO_4^{2-}.
- Constituents of cell membrane certain proteins, all nucleic acids and required in **phosphorylation reaction**.

Potassium :

- Absorbed as potassium ion (K^+)
- Required in meristematic tissues.
- Maintain cation and anion balance in cell.
- **Opening and closing** of stomata.
- Activation of enzyme.

- Maintenance of turgidity of cells.

Calcium :

- Absorbed in the form of calcium ions (Ca^{2+}).
- Required by meristematic and differentiating tissues.
- Used in synthesis of cell wall particularly as calcium pectate in **middle lamella**.
- Required during formation of **mitotic spindle.**
- Involved in normal functioning of cell membrane.
- Activate certain enzyme.
- Important role in regulating metabolic activity.

Magnesium :

- Absorbed in the form of Mg^{2+}.
- Activates enzymes of respiration, photosynthesis.
- Involved in the synthesis of DNA and RNA.
- Constituent of the **ring structure of chlorophyll**.
- Maintain **ribosome structure**.

Sulphur :

- Absorbed in the form of sulphate SO_4^{2-}.
- Present in two amino acids **cystine** and **methionine**
- Main constituent of several coenzyme, vitamins and ferredoxin.

Iron :

- Obtained in the form of ferric ions (Fe^{3+}).
- Required in larger amount in comparison to other elements.
- Constituent of proteins involved in the transfer of electron like **ferredoxin** and **cytochromes**.
- Activates catalase enzyme.
- Essential for formation of chlorophyll.

Manganese :

- Absorbed in the form of manganous ions (Mn^{2+}).
- Activates many enzymes of photosynthesis, respiration and nitrogen metabolism.
- **Photolysis of water** and evolution of oxygen during light reaction.

Zinc :

- Obtained in the form of Zn^{2+}.
- Activates enzymes like **carboxylase.**
- Required in **synthesis of auxin.**

Cupper :

- Absorbed in the form of cupric ions (Cu^{2+}).
- Essential for overall metabolism.

- Associated with enzyme involved in redox reactions.

Boron :

- Absorbed in the form of BO_3^{3-} or $B_4O_7^{2-}$.
- Required in **uptake and utilization of Ca^{2+}.**
- Pollen germination.
- Cell elongation.
- Cell differentiation.
- Carbohydrate translocation.

Molybdenum :

- Obtained in the form of molybdate ions (MoO_2^{2-}).
- Component of enzyme like **nitrogenase** and **nitrate reductase.**
- Required in nitrogen metabolism.

Chlorine :

- Absorbed in the form of chloride anion (Cl^-).
- Along with Na^+ and K^+ it determines the solute concentration.
- Maintain anion cation balance of the cell.
- Essential for **photolysis of water** during light reaction of photosynthesis.

Deficiency symptoms of essential elements :

- Critical concentration: the concentration of the essential element below which plant growth is retarded.
- The element is said to be deficient when present below the critical concentration.
- For the elements that are actively mobilized within the plant that show the deficiency symptoms in the older tissues. (nitrogen, potassium and magnesium)
- The deficiency symptoms tend to appear first in the young tissues whenever the elements are relatively immobile and are not transported out of the mature organs.(sulphur and calcium)
- Deficiency symptom includes chlorosis, necrosis, and stunted growth, premature fall of leaves and buds, and inhibition of cell division.
- **Chlorosis:** is the loss of chlorophyll.
- **Necrosis:** death of cells and tissues.

Toxicity of Micronutrients :

- Micronutrient required in low amount.
- Moderate decrease causes the deficiency symptoms.
- Moderate increase causes toxicity.
- Any mineral ion concentration in tissues that reduces the dry weight of the tissues by 10 percent is considered **toxic**.

Nitrogen cycle :

- **Nitrogen fixation**: conversion of molecular nitrogen into ammonia.
- **Biological nitrogen fixation**: Conversion of atmospheric into organic compounds by living organisms.
- **Ammonification:** decomposition of organic nitrogen of dead plants and animals into ammonia is called Ammonification. (***Nitromonas***bacteria)

- **Nitrification.** Ammonia oxidized into nitrite by ***Nitrosomonas***and***Nitrococcus*** bacteria. The nitrite further oxidized to nitrate with the help of ***Nitrobacter*.** These steps are called nitrification.

- **Assimilation:**
  - Nitrates absorbed by plant from soil and transported to the leaves.
  - In the leaves nitrates reduced to form ammonia that finally forms the amine group of amino acids.

- **Denitrification:** Nitrate in the soil is also reduced to molecular nitrogen. This process is carried by bacteria like***Pseudomonas*** and ***Thiobacillus.***

Biological nitrogen fixation :

- Reduction of nitrogen to ammonia by living organisms is called biological nitrogen fixation.
- The enzyme nitrogenase which catalyses the process are present in prokaryotes, called nitrogen fixer.
- Nitrogen fixing microbes could be free-living or symbiotic.
- 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.

Symbiotic nitrogen fixation :

- 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.**

Nodule formation :

- Nodule formation involves a sequence of multiple interactions between Rhizobium and roots of the host plant.
- *Rhizobia* multiply and colonize the surroundings of roots and get attached to the epidermal and root hair cells.
- An infection thread is produced carrying the bacteria into the cortex of root.
- Bacteria released from the thread into the cells which differentiated into special nitrogen fixing cells.
- Nodule develops vascular connection for exchange of nutrients.
- The nodule contains an enzyme called **nitrogenase.**
- Nitrogenase is a Mo-Fe protein and catalyses the conversion of atmospheric nitrogen to ammonia.
- Nitrogenase is highly sensitive to molecular oxygen; it requires anaerobic condition.
- Nodule contains a special protein called **leg-haemoglobin**.
- 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.

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.
- **Transamination:** it 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 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.