UNIT IV-Mineral Nutrition

Synopsis

- Minerals are absorbed by the plants from the soil in the ionic form dissolved in water. Aquatic plants and epiphytes are no exception.
- All the minerals present in soil in a location are not absorbed by the plants. Different plant groups absorb different elements from the soil.
- All the plants do not have similar mineral composition in their bodies.
- Daniel Arnon and Perry Stout proposed criteria of essentiality to know which elements are essential for the plants proper growth.
- His three criteria are

  1. Deficiency of the element makes it impossible for the plant to complete the vegetative or reproductive stage of its life cycle.

  2. Such deficiency must be specific to that element in question and can be prevented or corrected by supplying only that element.

  3. The element is directly involved in the nutrition of the plant.
- Some elements violate 2^{nd} & 3^{rd} criteria. For example Bromine replacing Chlorine. Potassium does not participate directly in metabolic activities of the plant.
- Based on this essential criterion 16 elements are identified as essential. Some of them are required in large quantities and are called as macro elements and some in minute amounts are microelements.
- Macro elements are 9. They are H, C, O, N ,K ,Ca, Mg, P & S. Among these Hydrogen, Carbon and Nitrogen are not obtained from soil as minerals.
- Microelements are Chlorine, Boron, Iron, Manganese, Zinc, Copper, and Molybdenum. These are 7.
- Nitrogen can be absorbed as anion or cation from the soil (nitrate, nitrite and ammoniacal form). Molecular form can be utilized by certain prokaryotes like *Rhizobium, Nostoc, Anabaena* etc.
- If plants are exposed to low amounts of nutrients they develop deficiency symptoms that can be corrected by external supplement in the form of fertilizers.
- Nitrogen deficiency first appears in older leaves and yellowing is the symptom. Later anthocyanins appear in the veins.
- Phosphorous deficiency can be confused with nitrogen deficiency in anthocyanin accumulation. Necrotic areas develop on the older leaves.

- Deficiency symptoms of calcium appear first in young leaves .Leaf tips hook.
- Magnesium deficiency produces extensive interveinal chlorosis in older leaves.
- Mottled chlorosis, necrosis of tip and margins of basal leaves is the deficiency symptom of Potassium.
- Sulfur deficiency appears first in young leaves. Symptoms look like that of nitrogen deficiency.
- Interveinal chlorosis in young leaves appear in Iron deficiency.
- Manganese deficiency produces chlorotic and necrotic spots in the interveins.
- Copper deficiency produces 'Exanthema' (gummy exudates) in fruit trees and 'Reclamation' (chloris of leaf tips) in cereals.
- Interveinal chlorosis of old leaves starting from tip and margins, rosette appearance, 'little leaf 'disease are diseases of Zinc deficiency.
- Boron deficiency causes death of shoot tip and thick coppery texture of leaves.
- Molybdenum deficiency causes chlorosis and mottling of lower leaves, it causes 'whiptail' disease in cauliflower.
- Absorption of nutrients is a active process crossing membranes through porters (membrane proteins).
- Some porters are uniporters that allow entry of only one element in uni direction involving biological energy in the form of hydrolysis of ATP.

  E.g. H^+ - ATPase and Na^+ - ATPase.
- Hydrolysis of ATP leads to accumulation of proton on the outer side of the membrane. This proton motive force developed due to potential difference of protons helps in the transport of elements inside along with protons. This is co-transport. In co-transport if elements move in one direction that is symport.
- Symport derives energy from proton motive force. This also referred as Secondary active transport.eg. H+ coupled NO^-_3 or Cl^- or PO^-_4.
- Antiporters allow movement both sides simultaneously of the same charged ion.
- Use of biofertilizers is safe to supplement additional nutrients to the plants. These are microorganisms.
- *Rhizobium* can be used in growing leguminous plants. They form symbiotic association.
- *Azospirillum*, an associate symbiont in grass plants is used in dry land forming of cereals. **E.**g. Sorghum, bajra, wheat, maize, barley and finger millet.
- Cyanobacteria can be used only in paddy fields. It also can be used as green manure.

- *Azolla* , a water fern that associate symbiotically with Anabaena azollae effectively used in paddy fields. *Azolla pinnata* shows heavy metal tolerance.
- Cultivation of microorganisms used as biofertilizers, transport and storage of these are disadvantages.
- Mycorrhiza (VAM) is advantageous in dry lands as the association increases longevity, resistance, absorbance of nutrients to the plant.

  E.g. Use of *Glomus* on potato, wheat, maize, soybean, red gram etc.

NITROGEN METABOLISM

Synopsis

- Nitrogen absorbed by the plants undergoes transformations to organic plant constituents. This process is referred as assimilation.
- 79% of gaseous components of the atmosphere are nitrogen. It is present in dinitrogen form. Only prokaryotes have the ability to fix this nitrogen form.
- Nitrogen fixation is the chemical reaction of nitrogen with other chemical molecules. Nitrogen can react with oxygen hydrogen and carbon.
- In the upper strata of the atmosphere during thunderstorm and lightning nitrogen reacts with oxygen to form oxides of nitrogen which washed down to the earth by water molecules forming acids of nitrogen.
- Nitric acid dissociate into nitrate and hydrogen in the soil.
- Nitrogen is fixed by industrial process in the manufacture of ammonia fertilizers. These processes are abiological-without involving biological systems.
- Biological nitrogen fixation takes place with the help of certain bacteria symbiotically or non-symbiotically.
- Absorbed nitrogen will be incorporated into amino acids by the plants.
- Nitrogen in the soils are available to roots higher plants in the nitrate form mostly .Ammonium fertilizers supplied to the soils are converted into nitrates by soil bacteria into nitrates. This is called nitrification.
- In water logged soils nitrogen is available in ammonical form.
- The absorbed nitrates by the plants is reduced to ammonia in the cells in the presence of enzymes nitrate reductase and nitrite reductase.

- Nitrate reductase is present in cytosol and nitrite reductase is in plastids. Respiratory energy is utilized in this non-chlorophyllous sells.
- Alternatively the absorbed nitrates are transported to leaves where it is converted into ammonia in the chloroplasts. Energy from sun light will be utilized.
- Nitrate reductase contains molybdenum.
- Ammonia after formation is incorporated into amino acids by reacting with glutamic acid. Glutamine is the first amino acid formed during nitrogen assimilation.
- Light, carbohydrate status is essential for these reactions.
- Symbiotically associated bacteria like *Rhizobium* helps in biological nitrogen fixation.
- Plant root exudates are identified by the bacteria and approach the plant. These reactions are highly specific.
- Entry of bacteria always through root hairs. Roots undergo curling due to the factors released by the bacteria.
- Bacterial enzymes dissolve the cell wall and bacteria enter the cell but never penetrate plasma membrane.
- Bacteria multiply and push the membrane to form a thread like structure called infection thread.
- Inside the cortex, due to interaction the bacteria loose its rod shape and form spherical structures called bacteroides. It will be covered by a membrane donated by the host plant.
- Host and bacteria together produce Leg-hemoglobin an oxygen carrying protein and an enzyme nitrogenase that reduces the nitrogen.
- Nitrogenase is a dimer of two sub units. Large sub unit is a tetramer with molybdenum, small one is dimer with iron.
- Energy is provided by the electron transport chain of the bacteria. 16 ATP are required for a molecule of nitrogen to reduce two molecules of ammonia.
- The first amino acid formed in symbiotic associations is asparagine.
- After the death of the organism, ammonia is released from amino acids and protein by ammonification.
- In nature nitrogen cycle (biogeochemical cycle of nitrogen) operates by various processes. Atmospheric nitrogen is fixed (nitrogen fixation) by biological or abiological means to form ammonia or nitrates. Plants absorb nitrates and ammonia and assimilate into organic compounds like amino acids and proteins. After death and decay of the animals and plants by ammonifying bacteria releases ammonia into the atmosphere (ammonification).Ammonia converted into nitrates by nitrifying bacteria (nitrification).

Denitrifying bacteria reduces nitrates into dinitrogen (denitrification) thus completing the cycle.

- Nitrogen fixing bacteria may be aerobic and free living (*Azotobacter*) or anaerobic free living (*Clostridium, Methanococcus*) . All photosynthetic bacteria are anaerobic. Bacteria like *Rhodospirillum, Chromatium ,Rhodopseudomonas f*ixes atmospheric nitrogen. Cyanobacteria or blue green algae are free living and some of them also form symbiotic association with different plants.

PROTEIN SYNTHESIS

Synopsis

- Proteins are polymers of amino acids. Sequence of amino acids is specific for every protein. The sequence of nucleotides in the DNA decides the sequence of amino acids in the protein. This relation ship is called genetic code.
- The code present in DNA is transcribed into mRNA (transcription).During transcription a single coding strand (5'→3') copied its sequence into mRNA. Non coding strand acts as template. Enzyme RNA polymerase participates. This is a slow process compared to translation. In prokaryotes both transcription and translation takes place simultaneously as nuclear membrane is absent.
- Translation in three different steps –Chain initiation, Chain elongation and Chain termination.
- Chain initiation is complex and time consuming. mRNA is identified by small sub unit of ribosome. With help initiation factors and energy in the form of ATP and GTP initiation complex is formed. In the initiation complex a complete ribosome is attached to the mRNA at initiation site with initiation codon AUG. The two cavities are filled with tRNAs carrying amino acids. Specific aminoacyl synthase enzyme participates in charging the tRNA with amino acid.
- In the chain elongation peptide bond is formed between amino acids being carried by tRNAs. Chain elongation always takes place in N→C direction. Enzymes peptidyl transferase and translocase participates. Ribosome moves toward right side by three nucleotide sequence. This is fast reaction.
- Chain termination ends the chain when ribosome reaches termination codons (UAA, UAG, UGA).