6. Plant Water Relations and Mineral Nutrition

- **Translocation**
  - It is a biological process that involves the transport of dissolved material within a plant.
  - It mainly occurs with the help of xylem and phloem.
  - The transport of food from leaves to other parts of plant occurs by phloem. Movement of food in phloem is bidirectional.
  - The conduction of water and minerals from soil to the rest of the plant occurs by xylem. Movement of water in xylem is unidirectional.
- **Need of Water and Minerals for Plants**
  - **Need of Water**
    - For photosynthesis
    - For transpiration
    - For transportation
    - For mechanical stiffness
  - **Need of Minerals**
    - Needed as nutrients for the plants
    - For the synthesis of a variety of compounds and enzymes

- **Means of Transport**
- **Diffusion**
  - It is the spontaneous movement of molecules from a region of high concentration to a region of low concentration.
  - It is a slow process and does not require any energy expenditure.
  - It does not require a semi-permeable membrane and can take place through any membrane along concentration gradient.
  - Rate of diffusion is affected by
    - a. concentration gradient
    - b. membrane permeability
    - c. temperature
    - d. pressure
- **Facilitated diffusion**
  - It involves the movement of molecule from the region of higher concentration to lower concentration, mediated by a carrier (mainly protein) molecule.
  - Movement of molecules across membrane occurs without expenditure of energy.
  - **Porins –** They are large protein molecules that form pores in membranes of plastids, mitochondria, and some bacteria
  - Porins allow the movement of small-sized proteins across membrane. Aquaporins are proteins, which form a water-permeable channel.
  - Some protein molecules allow diffusion only if two molecules are present. Based upon the direction which is followed by both molecules, the path can be of three types.
  - **Symport –** when both molecules cross the membrane in same direction
  - **Antiport –** when both the molecules move in the opposite directions
  - **Uniport –** when single molecule moves across a membrane independent of other molecule
- **Active transport**
  - It involves the transport of molecules from a region of low concentration to a region of high concentration with an expenditure of energy.
  - It is carried out by membrane proteins.

- **Osmosis**
  - Osmosis is a special type of diffusion which involves the movement of water molecules from the region of high concentration to the region of low concentration through a semi-permeable membrane.
  - Semi-permeable membrane = Selectively permeable membrane.
  - Types of Osmosis:
    - Endosmois
    - Exosmosis
  - Rate of osmosis is affected by
    (i) pressure gradient
    (ii) concentration gradient
  - Osmotic pressure is the hydrostatic pressure produced by a difference in concentration between solutions on the two sides of a semi-permeable membrane.
  - **Tonicity** : Relative concentration of solution and its surroundings.
  - **Isotonic solution:** Solution that has the same salt concentration as the normal cells
  - **Hypotonic solution:** Solution that has lower salt concentration than the normal cells
  - **Hypertonic solution:** Solution that has higher salt concentration than the normal cells
  - **Important terms : Flaccidity, Turgidity, Plasmolysis, Deplasmolysis,Wall Pressure.**
- **Plasmolysis**

- It is the contraction of cells within plants due to the loss of water through osmosis.
- When cells are placed in hypertonic solution, a cell tends to lose water to the surrounding solution due to exosmosis. The plasma membrane shrinks and the cell is said to be plasmolysed.
- When cells are placed in hypotonic solution, cells get deplasmolysed (turgid) due to movement of water into the cell from surrounding as a result of endosmosis.

- **Deplasmolysis**
  - The opposite of plasmolysis.
  - If not dead, the protoplasm absorbs water
  - The cell swells up
- **Difference between Diffusion and Osmosis**
-

Diffusion	**Osmosis**
1 Movement of substances from higher concentration to lower concentration.	Movement of selective substances through a semi-permeable membrane.
2 It occurs in any medium	It occurs in liquid medium.
3 It helps in equalising the concentration in the available space.	It does not equalise the concentration of solvent on either sides.
4 It does not depend on solute potential	It depends on the solute potential.

- **Imbibition:** It is a special type of diffusion which involves water absorption through colloids causing tremendous increase in volume. For example: absorption of water by seeds and dry wood

- **Plant – water relation**
- **Water potential (ψ_w):**
  - Water potential is the potential energy of water relative to pure free water (e.g. deionized water) in reference conditions. It quantifies the tendency of water to move from one area to another due to osmosis, gravity, mechanical pressure, etc.
  - Water potential of pure water at standard temperature and under no pressure is taken as 0.
  - Water potential is determined by solute potential (ψ_s) and pressure potential (ψ_p).

    $\psi_w = \psi_s + \psi_p$
  - **Solute potential:** Solute potential is a measure of the change in water potential of a system due to the presence of solute molecules. More the solute molecules, lower (and more negative) will be the solute potential.
  - Solute potential is always negative.
  - **Pressure potential:** When water potential of pure water increases on application of pressure more than the atmospheric pressure, it is termed as pressure potential.
  - Pressure potential plays a major role in ascent of water through stem.

- **Long distance water transport**

- **Mass or bulk flow system:** It involves movement of substance as a result of pressure difference.

- **Absorption of water**

- **Two pathways:**

i. **Apoplast pathway –**

- It involves movement of water through adjacent cell walls of the epidermis and cortex.
- Movement is restricted at casparian strips of endodermis.

ii. **Symplast pathway –**

- It involves movement of water through interconnected protoplast of epidermis, cortex, endodermis, and root pericycle.
- The intercellular movement is through plasmodesmata.

  - **Mycorrhiza** is a symbiotic association of fungi with root systems of some plants. Fungi help in absorption of water and minerals from soil by forming fungal hyphae.

- **Water movement**
- **Root pressure**
  - It is the positive pressure that develops in the roots of plants by active absorption of nutrients from soil.
  - It pushes the water up to small heights.
  - Root pressure is linked to the phenomenon of guttation.
  - Guttation: It involves the loss of water in the form of liquid droplets through the vein endings of the leaves.
  - Guttation occurs early in the morning and late in the evening when evaporation is low and root pressure is high.
- **Transpiration Pull**
  - Water transport in tall trees occurs by transpiration pull.
  - Transpiration pull is generated by transpiration. It is also called cohesion - tension - transpiration pull model of water transport.
  - The ascent of xylem sap is dependent on three physical properties of water:
    - Cohesion
    - Surface tension
    - Adhesion

Transpiration

- It is the loss of water in the form of water vapour through stomata.

Types of Transpiration

- Stomatal transpiration- Occurs through stomata
- Cuticular transpiration- Occurs through surface of stem and leaves
- Lenticular transpiration- Occurs through lenticels

Differences between Evaporation and Transpiration

Evaporation	Transpiration
Loss of water from the surface in the form of water vapours	Loss of water from aerial parts of plants in the form of water vapours
Fast process	Slow process
A physical change controlled by temperature and pressure	A partially physical and vital process controlled by various internal and external factors

Transportation

It is a life process where substances synthesised or absorbed in one part of the organism's body are carried to other parts of the body.

Translocation in plants

- The translocation system in plants moves the synthesised food from leaves to remaining plant parts. It also helps in moving raw materials absorbed from the roots to various organs of the plant.
- **Phloem** transports food materials from the leaves to different parts of the plant body.
- The phloem consists of companion cells, sieve tubes, phloem parenchyma, and fibres.
- Transport of food (translocation) through phloem requires energy, which is obtained from respiration in the form of ATP.

  - Soil becomes deficient in nutrients after harvesting.
  - Manures and fertilizers contain essential nutrients like nitrogen, phosphorous and potassium.
  - Manures and fertilizers are added from time to time so that soil regains its fertility.

- **Nutrient management**
  - There are 16 nutrients that are essential for plants
  - Carbon, hydrogen and oxygen are called the framework elements
  - The nutrients required in relatively large quantity for growth and development of plants are called **macro nutrients.** These are nitrogen, phosphorous, potassium, calcium, magnesium and sulphur
  - The nutrients required in small quantity are called **micro nutrients.** These are iron, manganese, boron, zinc, copper, molybdenum and chlorine.

Biological nitrogen fixation

- Biological nitrogen fixation is the process whereby atmospheric nitrogen (N≡N) is reduced to ammonia in the presence of enzyme nitrogenase (exclusively present in prokaryotes).
- Enzyme nitrogenase is a Mo – Fe protein and catalyses the conversion of atmospheric nitrogen to ammonia.
- Nitrogen fixing microbes such as *Azotobacter* and *Beijernickia* are aerobic nitrogen fixers. *Rhodospirillum* is anaerobic nitrogen fixer and *Bacillus* is a free-living nitrogen fixer.

Symbiotic nitrogen fixation

- Legume-bacteria relationship is an example of symbiotic biological nitrogen fixation.
- Nitrogen fixing bacteria (eg. *Rhizobium*) live in the root nodules of leguminous plants.
- *Frankia* produces nitrogen-fixing nodules in non-leguminous plants.
- Leghaemoglobin pigment helps in the process of nitrogen fixation.
- Reaction of nitrogen fixation-

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

- The ammonia produced by the above reaction is used to synthesize amino acids in plants.
- Conversion of ammonia to amino acids takes place by either reductive amination or transamination.

  - **Nitrogen cycle**