WATER RELATIONS IN PLANTS

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Water Potential

- According to thermodynamic laws every component of a system possesses free energy capable of doing work under constant temperature conditions.
- Osmotic movement of water involves certain work done and infact the main driving force behind this movement is the difference between free energies of water on two sides of semi permeable membrane .
- For nonelectrolytes, free energy/mol. is known as chemical potential (denoted by Greek letter psi Ψ) with reference to water this is called water potential.
- The movement of water will take place in osmotic or other systems from a region of higher water potential to a lower water potential.

Osmotic Potential

- Osmotic pressure in a solution results due to the presence of solutes .
- osmotic pressure is a quantitative index of the lowering of water potential in a solution

thermodynamic terminology is called osmotic potential.

- Osmotic potential is also called **solute potential**

designated ψ_s because it is the contribution due to dissolved solute.

Pressure Potential

In a closed osmotic system eg., in the plant cell a pressure is imposed on water which increases the water potential.

In plant this pressure is called turgor pressure.

This is the actual pressure with positive sign and ranges between zero and numerical osmotic potential value.

The potential created by such pressure is called as pressure potential (Ψ p)

Absorption of Water

- **Water** is highly essential for **plants** for various metabolic activities. Land plants get their water supply from soil which serves as the source of water and **minerals** to them.

- The way in which water from soil enters roots, particularly to the root xylem, is called "mechanism of water absorption".

Mechanism: Two Types

- **1. Active absorption**
- **2. Passive absorption**

Active Absorption

- The root cells play active role in the absorption of water and metabolic energy released through respiration consumed.

- Two types

Osmotic absorption: water is absorbed from the soil into the xylem of roots according to the osmotic gradient .

Non osmotic absorption: water is absorbed against the osmotic gradient.

Passive Absorption

- Mainly due to transpiration, the root cell do not play active role and remains passive.
- Rapid evaporation of water from the leaves during transpiration creates a tension in water in the xylem of the leaves.
- This tension is transmitted top water in xylem of roots through the xylem of stem and the water rises upward to reach the transpiring surfaces.
- Soil water enter into the cortical cells through root hairs to reach the xylem of roots to maintain the supply of water. Force is created in leaves due to rapid transpiration hence the root cells remains passive.

Factors Affecting Absorption of Water

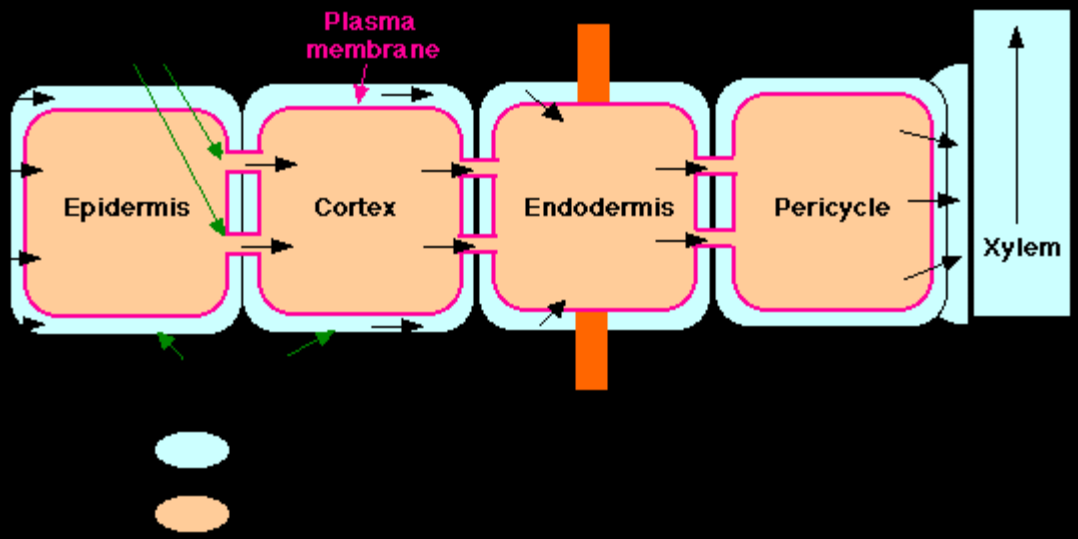
1. Available Soil Water: usually plant absorb capillary water. Increased amount of water in the soil beyond a certain limit in poor aeration of the soil which retard the metabolic activities of root cells like respiration and hence, the rate of water absorption is also retarded.

2. Concentration of Soil Solution : increased conc. Of soil solution results in higher osmotic pressure, if it is high then the cell sap in root cells become high then the osmotic absorption of water will be suppressed.

3. Soil Air: Absorption of water is retard in poorly aerated soils because in such soils deficiency of O_2 and consequently the accumulation of CO_2 will retard the metabolic activities of the root like respiration also inhibit the rapid growth and elongation of the roots so they are deprived of the fresh supply of water in the soil.

4. Soil Temperature: increase in soil temperature upto about 30 ^{0} C favour for water absorption . At higher temperature and low water absorption is decreased

The Pathway of Water



Soil water enters the root through its epidermis. It appears that water then travels in both

the cytoplasm of root cells — called the **symplast** — that is, it crosses the plasma membrane and then passes from cell to cell through **plasmodesmata**.

in the nonliving parts of the root — called the **apoplast** — that is, in the spaces between the cells and in the cells walls themselves. This water has not crossed a plasma membrane

- However, the inner boundary of the cortex, the **endodermis**, is impervious to water because of a band of lignified matrix called the **casparian strip**.

- Therefore, to enter the stele, apoplastic water must enter the symplasm of the endodermal cells. From here it can pass by **plasmodesmata** into the cells of the stele.

- Once inside the stele, water is again free to move between cells as well as through them. In young roots, water enters directly into the **xylem** vessels and/or tracheids. These are nonliving conduits so are part of the apoplast.

- Once in the xylem, water with the minerals that have been deposited in it (as well as occasional organic molecules supplied by the root tissue) move up in the vessels and tracheids.

- At any level, the water can leave the xylem and pass laterally to supply the needs of other tissues. At the leaves, the xylem passes into the petiole and then into the veins of the leaf.

- Water leaves the finest veins and enters the cells of the spongy and palisade layers. Here some of the water may be used in metabolism, but most is lost in transpiration.

Water and transport

- Less than 1% of the water reaching the leaves is used in photosynthesis and plant growth. Most of it is lost in transpiration.

- Ascent of sap

  The water after being absorbed by the roots is distributed to all parts of the plant (excess of which is lost through transpiration). In order to reach the topmost parts of the plant, the water has to move upward through the stem.

  This upward movement of water is called Ascent of Sap

  It take place through Xylem

Absorption of ions

- Absorption of mineral salts is the process of Ion exchange which does not require metabolical energy but greatly facilitates mineral salts absorption.

- Ion Exchange

  Ions adsorbed on the surface of the walls or membranes of root cells may be exchanged with the ions of same sign from external solution the cation K+ of the external solution may be exchanged with OH- ions

Types : Two types of absorption

1. Passive Absorption

- When the concentration of mineral salts is higher in the outer solution than in the cell sap of the root cells, mineral salts are absorbed according to the concentration gradient by simple process of diffusion.
- It does not require expenditure of metabolic energy.

2. Active Absorption

- Cell sap accumulates large quantities of mineral salts ions against the concentration gradient
- It involves the expenditure of metabolic energy through respiration.
- The active absorption of mineral salts involves the operation of the carrier compound present in the plasma membrane of the cells.

Transport

- Molecular and ionic movement from one location to another is known as **transport.**

Two types : Passive and Active

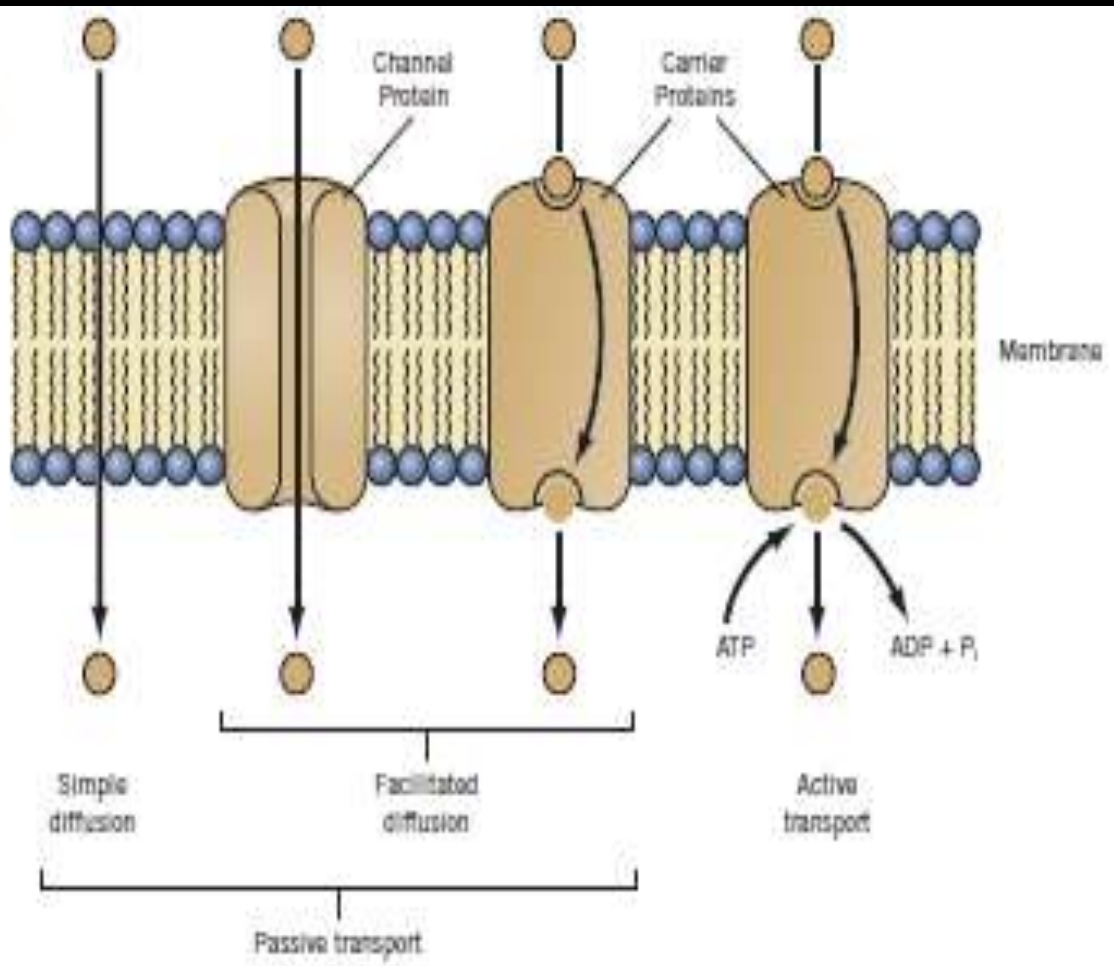
Passive Transport

- The movement of molecules by diffusion always proceeds spontaneously, down a gradient of concentration or chemical potential, until equilibrium is reached.
- The spontaneous "downhill" movement of molecules is termed **passive transport**.
- At equilibrium, no further net movements of solute can occur without the application of a driving force

Active Transport

- Active transport is the pumping of molecules or ions through a membrane **against** their concentration gradient. It requires: a transmembrane protein (usually a complex of them) called a transporter and energy. The source of this energy is **ATP**.
- The energy of ATP may be used directly or indirectly.
- **Direct Active Transport.** Some transporters bind ATP directly and use the energy of its hydrolysis to drive active transport.
- **Indirect Active Transport.** Other transporters use the energy already stored in the gradient of a directly-pumped **ion**. Direct active transport of the ion establishes a concentration gradient. When this is relieved by facilitated diffusion, the energy released can be harnessed to the pumping of some other ion or molecule.

FIGURE 3.3 The exchange of ions and solutes across membranes may involve simple diffusion, facilitated diffusion, or active transport.



Soil-Plant-Atmosphere Continuum (SPAC)

- The pathway for water moving from soil through plants to the atmosphere.

The transport of water along this pathway occurs in components, variously defined among scientific disciplines:

- Soil physics characterizes water in soil in terms of tension,
- Physiology of plants and animals characterizes water in organisms in terms of *diffusion pressure deficit*, and
- Meteorology uses vapour pressure or relative humidity to characterize atmospheric water.

SPAC integrates these components and is defined as a:

- It recognising that the field with all its components (soil, plant, animals and the ambient atmosphere taken together) constitutes a physically integrated, dynamic system in which the various flow processes involving energy and matter occur simultaneously and independently like links in the chain.

- This characterises the state of water in different components of the SPAC as expressions of the energy level or water potential of each.

- Modelling of water transport between components relies on SPAC, as do studies of water potential gradients between segments.

Stomatal physiology and regulation

TRANSPIRATION

- The excess of water is lost from the aerial parts of plants in the form of water vapours.

- Two kinds of transpiration

1.Stomatal – takes place through stomata

2. Cuticular (peristomatal) – although cuticle is impervious to water still water may be lost through it.

3. Lenticular- some water may be lost by woody stems through lenticles (transpiration from leaves – foliar transpiration)

Mechanism of stomatal transpiration

- Takes place during day time

3 steps

1. Osmotic diffusion: water in the leaf from xylem to intercellular spaces through mesophyll cells.
2. Opening and closing of somata (somatal movement)
3. Simple diffusion: water vapours from intracellular spaces to outer atmosphere through stomata.

- The epidermis of leaves contains pores that provide for the exchange of gases between the internal air spaces and the ambient environment.

- The opening, or stoma, is bordered by a pair of unique cells called **guard cells**. In most cases the guard cells are in turn surrounded by specialized, differentiated epidermal cells called **subsidiary cells.**

- **The stoma, together with its** bordering guard cells and subsidiary cells, is referred to as the **stomatal complex, orstomatal apparatus.** The distinguishing feature of the stomatal complex is the pair of guard cells that functions as a hydraulically operated valve.

- Guard cells take up water and swell to open the pore when CO_2 is required for photosynthesis, and lose water to close the pore when CO_2 is not required or when water stress overrides the photosynthetic needs of the plant.

- Importance of stomata in regulating gas exchange and consequent effects on photosynthesis and productivity.

Translocation

- The movement of organic food materials or the solutes in soluble from one place to another in higher plants is called Translocation of organic solutes.

- It is essential for higher plants because

  1. Only the green parts can manufacture food and it must be supplied to other non green part for consumption and also for storage.

  2. During the germination of the seeds the insoluble reserve food material is converted into soluble form and is supplied to the growing regions of young seeding till it has developed its own photosynthetic system ie., leaves.

  The organic solutes always takes place from the region of higher concentration of soluble form ie. The supply end to the lower concentration of its soluble form ie., the consumption end.

Direction of Translocation

1. Downward Translocation- the organic food material is manufactured by leaves and is translocated downward to stem and the roots for consumption and storage.

2. Upward Translocation - During the germination of the seeds, tubers etc. when stored food is converted into soluble form and is supplied to the upper growing parts of young seeding till it has developed leaves.

   Also takes place through stem 1. to buds which resume growth in the spring 2. to developing leaves situated closer to its apex 3. to opening flowers and developing fruits which are situated near the ends of the branches.

3. Radial Translocation – takes place from the cells of the pith to cortex.

- Path of the downward translocation:

  Takes place through phloem

  1. Tissues other than phloem cannot account for downward translocation
  2. blocking of phloem
  3. chemical analysis of phloem sap
  4. isotopic studies
  5. ringing experiment

- Path of the upward translocation: Although takes place through phloem but certain condition through xylem

- Path of the radial translocation: Takes place from pith to cortex through medullary rays.

- **Mechanisms for** translocation may be classified as either *active or passive,* depending on whether metabolic energy is expended in the process. It is sometimes difficult to distinguish between active and passive transport, but the translocation of water is clearly a passive process.

- Although in the past many scientists argued for an active component, the evidence indicates that water movement in plants may be indirectly dependent upon on expenditure of metabolic energy.

- Passive movement of most substances can be accounted for by one of two physical processes: either **bulk flow or diffusion. In the case of water, a** special case of diffusion known as **osmosis must also be** taken into account.

References

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