B.Sc. II year (Botany)

Plant water Relations

(Part -1)

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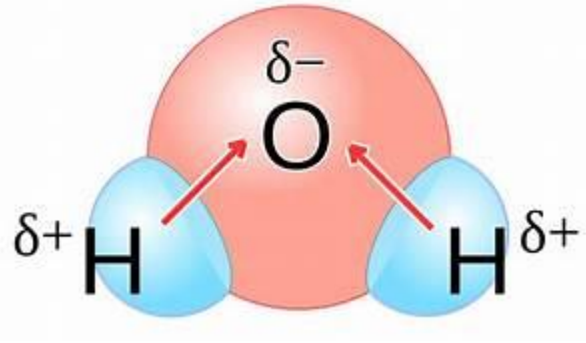
According to unified syllabus of Botany for U.P. State Universities.

Plant water Relations ????

Plant Water Relations are the study of the behavior of water with plants. It includes

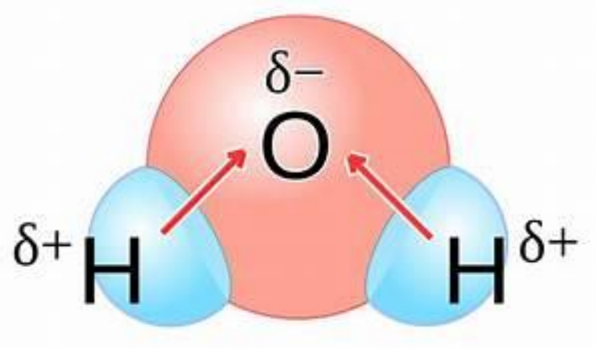
- Imbibition
- Diffusion,
- Osmosis,
- Absorption,
- Plasmolysis,
- Deplasmolysis,
- Ascent of sap,
- Wilting
- Transpiration,
- Translocation,
- Permeability,
- Turgor Pressure
- Wall Pressure

Properties of water



- Water molecule is polar
- Due to extensive hydrogen bonding that leads to high melting and boiling points, high specific heat (Specific heat is the amount of energy required to change the temperature of a substance), high latent heat of vaporization (which helps in the regulation of body temperature), high thermal conductivity, surface tension, dipole moment etc.
- As the temperature increases water density rises to 4°C and then decreases
- Amphoteric nature (Water can act as both acid and base)
- Redox reactions (electropositive elements reduce water to hydrogen molecule. Thus water is a great source of hydrogen.)
- During the process of photosynthesis, water is oxidized to O_2. As water can be oxidized and reduced, it is very useful in redox reactions.

Properties of water



- Hydrolysis reaction (water has a very strong hydrating tendency due to its dielectric constant. It dissolves many ionic compounds. Some covalent and ionic compounds can be hydrolyzed in water.)

- Water is an excellent solvent due to its high dielectric constant. It is able to dissolve a large number of different chemical compounds.
- Water molecules stay close to each other (cohesion), Water also has high adhesion properties because of its polar nature.
- Because water has strong cohesive and adhesive forces, it exhibits capillary action
- Water conducts heat more easily than any liquid except mercury.
- Water has a high surface tension (it tends to aggregate in drops rather than spread out over a surface as a thin film)

Water potential

- Free energy-Energy of system to do work
- Chemical potential- free energy per mole of any chemical substance (eg. water) in a solution
- Chemical potential of water is called as water potential (Ψw).
- Water always moves from the area of high water potential to the area of low water potential.
- Water potential of pure water at normal temperature and pressure is zero. This value is considered to be the highest.
- The presence of solid particles reduces the free energy of water and decreases the water potential. Therefore, water potential of a solution is always less than zero or it has negative value.

Components of Water potential

- **Water potential** is a measure of the potential energy in water.
- Water potential is the difference in potential energy between a given water sample and pure water (at atmospheric pressure and ambient temperature).
- Water potential is denoted by the Greek letter ψ (psi) and is expressed in units of pressure (pressure is a form of energy) called **megapascals** (MPa). The potential of pure water (Ψ_w) is zero.
- The water potential in plant solutions is influenced by solute concentration, pressure, gravity, and factors called matrix effects. Water potential has following components

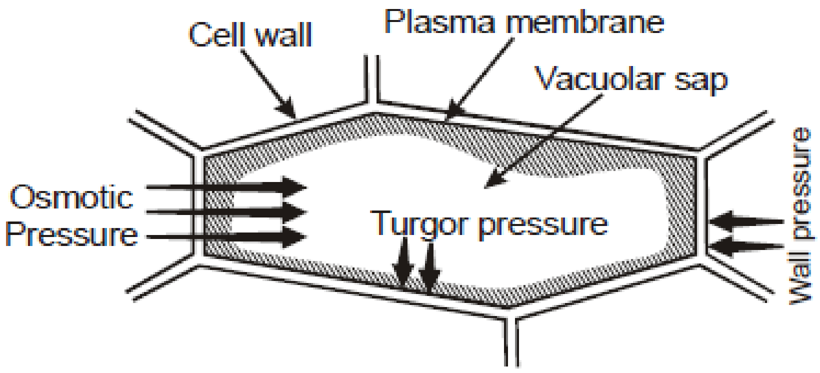
$$\Psi w = \Psi_s + \Psi_p + \Psi_g + \Psi_m$$

  where Ψ_s, Ψ_p, Ψ_g, and Ψm refer to the solute, pressure, gravity, and matric potentials, respectively. “

- As the individual components change, they raise or lower the total water potential of a system. When this happens, water moves to equilibrate, moving from the system or compartment with a higher water potential to the system or compartment with a lower water potential.

Pressure Potential

- Pressure potential (Ψ_p), also called turgor potential, may be positive, zero or negative.
- Because pressure is an expression of energy, the higher the pressure, the more potential energy in a system, and vice versa. Therefore, a positive Ψ_p (compression) increases Ψ_{total}, and a negative Ψ_p (tension) decreases Ψ_{total}.
- Positive pressure inside cells is contained by the cell wall, producing turgor pressure. Pressure potentials are typically around 0.6–0.8 MPa, but can reach as high as 1.5 MPa in a well-watered plant.



TURGOR PRESSURE

- An example of the effect of turgor pressure is the wilting of leaves and their restoration after the plant has been watered (Figure 3). Water is lost from the leaves via transpiration (approaching Ψ_p = 0 MPa at the wilting point) and restored by uptake via the roots.
- Ψ_p is also under indirect plant control via the opening and closing of stomata. Stomatal openings allow water to evaporate from the leaf, reducing Ψ_p and Ψ_{total} of the leaf.

Osmotic Relations of Cells According to Water Potential

- **In case of fully turgid cell:**

The net movement of water into the cell is stopped. The cell is in equilibrium with the water outside. Consequently the water potential in this case becomes zero.

$$\Psi_w = \Psi_s + \Psi_p$$
$$0 = \Psi_s + \Psi_p$$
$$\Psi_s = -\Psi_p$$

- **In case of flaccid cell:**

The turgor becomes zero(Ψ_p). A cell at zero turgor has an osmotic potential equal to its water potential. $\Psi_w = \Psi_s$

- **In case of plasmolysed cell:**

When the vacuolated parenchymatous cells are placed in solutions of sufficient strength, the protoplast decreases in volume to such an extent that they shrink away from the cell wall and the cells are plasmolysed. Such cells are negative value of pressure potential (negative turgor pressure).

Numerical Problems

1. Suppose there are two cells A and B, cell A has osmotic potential = -16 bars, pressure potential = 6 bars and cell B as osmotic potential = – 10 bars and pressure potential = 2 bars. What is the direction of movement of water?

Water potential of cell A = $\Psi_s + \Psi_p$ = – 16 + 6 = – 10 bars

Ψ of cell B = -10 + 2 = -8 bars.

As movement of water is from higher water potential (lower DPD) to lower water potential (higher DPD), hence the movement of water is from cell B to cell A.

2. If osmotic potential of a cell is – 14 bars and its pressure potential is 7 bars. What would be its water potential?

We know $\Psi_w = \Psi_s + \Psi_p$

Given, osmotic potential (Ψ_s) is – 14 bars.

Pressure potentials (Ψ_p) is 7 bars

Therefore,

Water potential = (-14) + 5 = – 9 bars.

Gravity Potential

- Gravity potential (Ψ_g) is always negative to zero in a plant with no height.
- It always removes or consumes potential energy from the system. The force of gravity pulls water downwards to the soil, reducing the total amount of potential energy in the water in the plant (Ψ_{total}).
- The taller the plant, the taller the water column, and the more influential Ψ_g becomes. On a cellular scale and in short plants, this effect is negligible and easily ignored. However, over the height of a tall tree like a giant coastal redwood plants are unable to manipulate Ψ_g.

Matric Potential

- Matric potential (Ψ_m) is always negative to zero.
- In a dry system, it can be as low as –2 MPa in a dry seed, and it is zero in a water-saturated system. The binding of water to a matrix always removes or consumes potential energy from the system.
- Ψ_m is similar to solute potential because it involves tying up the energy in an aqueous system by forming hydrogen bonds between the water and some other component.
- Every plant cell has a cellulosic cell wall and the cellulose in the cell walls is hydrophilic, producing a matrix for adhesion of water: hence the name matric potential.
- Ψ_m is very large (negative) in dry tissues such as seeds or drought-affected soils. However, it quickly goes to zero as the seed takes up water or the soil hydrates. Ψ_m cannot be manipulated by the plant and is typically ignored in well-watered roots, stems, and leaves.

Imbibition

- Imbibition is the process of adsorption of water by hydrophilic surfaces of a substance without forming a solution.
- It is a type of diffusion in which movement of water takes place along a diffusion gradient.
- The solid particles which adsorbed water are called imbibants.
- Imbibition pressure developed during the process because it exists due to the presence of hydrophilic substances in the cell which include organic colloids and cell wall.

Diffusion

- Diffusion is the process of movement of the molecules of solids, liquids and gases from the region of higher concentration to the region of lower concentration.
- It may occur between 1. Gas & Gas, 2. Liquid and liquid 3. Solid and liquid Diffusion occurs due to diffusion pressure. Diffusion pressure is the potential ability of the molecules or ions of any substance to diffuse from an area of their higher concentration to that of their lower concentration.
- Diffusion is very important to perform Gaseous exchange, transpiration, translocation etc biological activities.

Permeability

The degree of diffusion of gases, liquids and dissolved substances through a membrane is called the permeability of that membrane. Different types of membranes are differentially permeable.

Types of membranes

1.Permeable membranes: Allow free passes of solvent and most of the dissolved substances.

2.Impermeable membrane: Do not allow the entry of water, dissolved substances and gases.

3.Semipermeable membrane: the movement of solvent molecules only through them but prevent the movement of solute particles.

4.Selectively permeable membrane: It is also called the differentially permeable membrane because this type of membranes allows selective passage of solutes along with solvent through them.

Osmosis

- Osmosis as the movement of water from its higher concentration to the lower concentration is called osmosis or migration of solvent from a hypotonic solution to hypertonic solution through semipermeable membrane to keep the concentration equal.

Types of osmosis

- **Endosmosis:** The flow of water into a cell when it is placed in a solution whose solute concentration is less than that cell sap.
- **Exosmosis:** The outflow of water from a cell when it is placed in a solution whose solute concentration is more than that of cell sap

Osmotic concentrations

- **Hypotonic solution:** A solution whose osmotic concentration is less than that of cell sap or another solution.
- **Hypotonic solution:** A solution whose concentration is more than that of cell sap or another solution.
- **Isotonic solution:** It is equal to that of another solution or cell sap **Importance of osmosis**
- Water absorption by plants,
- Cell to cell movement of water
- The rigidity of plant organs
- Leaves turgidity
- Opening and closing of stomata,
- Movement of plants and plant parts

Plasmolysis

Plasmolysis is the shrinkage of the protoplast of a living cell from its cell wall due to exosmosis under the influence of a hypotonic solution.

Types of plasmolysis

1.Incipient plasmolysis: It is the stage of plasmolysis when the protoplast just begins to contract away from the cell wall.

2.Evident plasmolysis: It is the stage when the cell wall has reached its limit of contraction and the protoplast has detached from the cell wall.

Importance of plasmolysis

- Salting of pickles, meat, fishes etc
- Addition of sugar to jams, jellies, cut fruits etc
- Weeds killing
- Determining whether a particular cell is living or dead

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