TRANSPORT PHENOMENA IN PLANTS

MBOTCC-7
UNIT-1

M. Sc. Sem-II
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Introduction:

Plants, in addition to their role as primary synthesizers of organic compounds, have evolved as selective accumulators of inorganic nutrients from the earth's crust. This ability to mine the physical environment is restricted to green plants and some microorganisms; other life forms being directly or indirectly dependent on this process for their supply of mineral nutrients. The initial accumulation of ions by plants is often spatially separated from the photosynthetic parts, necessitating the transport of these inorganic solutes to the photosynthetic parts of the plant. The requirement for energy-rich materials by the accumulation process is thus provided by a transport in the opposite direction of organic solutes from the photosynthetic area. Transport phenomena in plants have been studied at the cellular level, the tissue level, and the whole plant level. The basic problems of analyzing the driving forces and the supply of energy remain the same for all systems, but the methods of approach and the results obtained vary widely.

DIFFUSION:

(i) A passive process involving the net movement of molecules/ions of a given substance from a region of higher concentration to that of a lower one by virtue of their kinetic energy till their respective concentrations become uniform and a state of dynamic equilibrium is achieved in the system.

(ii) Difference in concentration of the molecules/ions between two regions of the system acts as the driving force for their diffusion.

(iii) Amount of substance diffusing per unit cross sectional area of the surface per unit time is called Flux.

(iv) At equilibrium, net movement of molecules/ions in the system becomes zero, but the actual movement never ceases. That is why the term dynamic equilibrium is used.

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(v) Nature of the diffusion process is often called passive or spontaneous or exergonic or energy releasing or downhill.

(vi) Thermodynamically, the system loses energy and moves from a higher energy level to a low energy level (exergonic/energy losing).

(vii) Diffusion Pressure (DP) refers to the ability of molecules/ions to diffuse in a system which cannot be measured directly. An area or point in a system with higher concentration of molecules or ions is often said to have higher diffusion pressure.

(viii) Diffusion occurs along a DP gradient, i.e., from higher DP to lower DP.

(ix) Pure water (at STP) has the highest Diffusion Pressure (DP). Dissolution of a solute gradually decreases its DP. Thus, a solution is said to have lower DP than the pure solvent (water).

This decrease in diffusion pressure in pure water is on dissolving the solute in it is called Diffusion Pressure Deficit (DPD).

Thus, DPD = DP of pure water − DP of soln.

(x) Diffusion occurs against a DPD gradient.

(xi) Diffusion can account for transport of materials (molecules/ions) only up to shorter distances, usually of the dimensions of a cell wall/cell membrane thickness.

(xii) Rate of diffusion is directly proportional to temperature and inversely proportional to the density of medium through which diffusion occurs.

(xiii) Graham's Law of diffusion states that rate of diffusion of gases is inversely proportional to the square roots of their densities.

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$$

(xiv) Fick's law of diffusion states that the rate of diffusion is proportional to the surface area (available) and concentration difference and is inversely proportional to the thickness of the membrane.

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OSMOSIS:

Key Points: (i) Osmosis may be defined as the movement of water across a differentially permeable (selectively permeable) membrane along a gradient, i.e., from an area of higher concentration to an area of lower concentration.

(ii) Thus it is a special type of unilateral diffusion through a differentially permeable membrane (e.g., plasma membrane).

(iii) It helps plants to absorb water from the soil.

(iv) Diffusion pressure (DP) of pure water is maximum. If some amount of salt/solute/sugar is dissolved in it the diffusion pressure decreases. This decrease in DP is known as diffusion pressure deficit (DPD). It is to equalize this deficit in diffusion pressure that the solvent (water) is drawn into a solution.

(v) In land plants, water enters the root hairs on this principle.

(vi) Osmotic movement of water (solvent) into an osmotic system finally reaches an equilibrium when net flow of the solvent into the osmotic system stops due to a hydrostatic pressure generated in the system on account of osmotically accumulated water. This pressure is known as osmotic pressure (OP).

(vii) Osmotic Pressure may be defined as the maximum hydrostatic pressure developed by a solution (separated from the solvent by a differentially permeable membrane) to prevent the passage of solvent (water) molecules into the solution. The above OP is generated in the osmotic system on account of osmotic influx of the solvent (water) molecules from the pure solvent.

(viii) Osmosis also occurs when two solutions (of the same solute) of varying concentrations are separated by a differentially permeable membrane.

Water Potential (Ψ)

- Concept developed by Slatyer (1965)
- This concept of water potential

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is the most accurate way to explain osmotic
movement of water.
– This concept of water potential is
based on the concept of energy and thermo-
dynamics.
– According to this concept, water
potential of pure water is taken to be zero.
When any solute is dissolved in pure water,
water potential of the resulting solution
decreases below zero, i.e., becomes negative
(–ve). Thus, water potential (ψ) is a negative
concept.
Thus pure water has zero water
potential while a solution (aqueous) has a
–ve water potential.
– Water movement by osmosis occurs
from higher water potential to lower water
potential, i.e., along a water potential
gradient.
– At equilibrium, ψ becomes uniform
throughout the osmotic system.
– Gibb's Free Energy (or simply
free energy) is the amount of energy of a
system potentially available for work.
– Free energy per mole (6×10^{23} molecules)
of a chemical species is called Chemical
Potential.
– Chemical Potential of water (which
is also a chemical species) is called Water
Potential (ψ).
– Relationship between diffusion and
osmosis is expressed by the equation:
DPD = OP – TP
This equation clearly establishes that
influx of water into a living plant cell
can be explained both in terms of diffusion
and osmosis. This influx may be said to
be effected, on the one hand, on the basis of
differences in DP of water outside and inside
the cell, i.e., DPD. On the other hand osmotic
entry of water creates an opposite hydrostatic
pressure by the accumulating water in the
cell (Turgor Pressure, TP). Thus, here influx
of water depends on the difference of OP and
TP. So DPD has been equated with OP – TP in the

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above equation.

IMBIBITION:

(i) This refers to the soaking of water (or other liquids) by materials on account of their colloidal constituents.

(ii) Hydrophilic or lyophilic colloids present in the imbibant cause imbibition.

(iii) Fibres, wood pieces, dry seeds, gums, etc. are some common materials which can imbibe water.

– Rubber can imbibe ether, but not water while dry seeds can imbibe water but not ether. Thus, there must be an affinity between the constituents of the imbibant and the substance to be imbibed.

– Plant cell wall constituents contain colloidal substances which are responsible for imbibition of water.

(iv) Imbibition of water increases the volume of the imbibant which generates an outward pressure called imbibition pressure (= matric potential).

– Seed coat of germinating seeds burst due to this imbibition pressure (IP).

(v) Relationship between DPD, IP and TP is expressed as:

DPD – IP – TP

(vi) Different organic substances have different imbibing capacities.

(vii) Increase in temperature brings about an increased rate of imbibition.

(viii) Total volume of the imbibant plus the substance to be imbibed is always less after imbibition than before imbibition.

MASS FLOW

(i) This refers to the movement of molecules or ions en masse (in bulk).

(ii) Also known as Bulk flow / Convective flow.

(iii) Water movement in the tracheary elements of xylem (Tracheids & Vessels) is an example of mass flow.

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TRANSCELLULAR TRANSPORT:

(i) This is movement or transport of materials (water in particular) across a series of cells.

(ii) Water movement across the cortex of roots is a kind of transcellular transport.

PINOCYTOSIS:

(i) Intake or influx or engulfing of liquid droplets (e.g., water) by changes in the morphology of cell membranes is called pinocytosis.

(ii) Smaller unicellular organisms may procure water through this pinocytic process.

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