PLANT WATER RELATIONS

Absorption of water

Synopsis

- Water is the major constituent of all plant cells.
- Water is the solvent in which mineral nutrients enter a plant and transport from one part to the other.
- In photosynthesis the hydrogen atom in the water molecule is incorporated into organic compounds and oxygen atoms are released as O_2.
- Water is reactant in a number of metabolic reactions. (Eg. TCA cycle).
- More than 90% of water is absorbed by the plants by their roots from the zone of root hair. After absorption it is transported from cell to cell and from tissue to tissue.
- Movement of water is spontaneous. Movement depends on difference in water potential.
- Water moves from higher water potential to lower water potential.
- The term water potential is used by plant physiologists in place of chemical potential of water. The term was introduced by R.O.Slatyer and S.A.Taylor (1960).
- The chemical potential of an individual chemical substance in a system is the free energy of 1 mole ($6x10^{23}$molecules) of the substance.
- Water potential in a system is the amount of energy available in amole of water. It is a relative term comparing with pure water.
- Water potential is denoted by Greek letter ψ (psi). It is expressed in pascals or megapascals-Mpa (1 Mpa=10bars)
- Water potential is influenced by factors like temperature, pressure and solute dissolved (Osmolarity).
- Pure water shows maximum water potential. Water potential of pure water is 'Zero'. With addition of solute water potential decrease. Water potential can be 'zero' or negative values.
- At constant temperature the relation between water potential, solute potential and pressure potential is $\psi_w = \psi_s + \psi_p$.
- Higher the ψ_w; the greater the ability to supply water.
- Water potential can be measured by thermocouple psychrometer.
- It is used in measuring water deficit and water stress.

Osmosis, osmotic potential, solute potential

- The movement of water across the membrane is osmosis.
- Osmotic potential is the ability stop osmosis.
- In living systems enclosed by membranes osmotic potential is considered in place of solute potential. $\psi_w = \psi_o + \psi_p$. Or $\psi = \pi + P$ (π = osmotic potential)
- Water movement in plant cells is by two processes osmosis and imbibitions.
- Osmosis is demonstrated by osmometer. Pure water in a beaker is separated from solution by a membrane.
- At equilibrium hydrostatic pressure (osmotic potential) balances the osmosis.
- Osmotic potential like water potential is 'zero' or negative values.
- The phenomenon of plasmolysis depends on osmosis. When cell is placed in hypertonic solution (concentration of water is less) cells lose water and undergo plasmolysis.

- Imbibitions are absorption and adsorption by dead substances that have affinity for the substances being imbibed.
- In plant cells imbibitions is absorption and adsorption of water by insoluble, solid, hydrophilic protoplasmic and cell wall constituents. (eg; absorption of water by pea seeds, dry wood etc) .
- This expressed as matric potential T (tau).It always have high negative values. It is not considered in the transportation of water in living cells.

Pressure potential

- In a closed system, like plant cells, due to the entry of water the hydrostatic pressure develops. This is called Turgor pressure- the outwardly directed pressure exerted by the cell contents on the wall. It is equal in magnitude and opposite in direction to the wall pressure. This is the pressure potential.
- Pressure potential can be 'zero' or positive values.
- Plasmolysed cells have 'zero' or almost zero turgor pressure (flaccid condition).
- During periods of rapid transpiration negative turgor pressure develops (positive from outside). in xylem elements.
- Under natural condition a cell is usually at a state between zero turgor pressure and full turgor pressure.
- Water from the soil enters the root crossing cell wall by imbibitions. In living spaces (symplast) it moves by osmosis into the protoxylem elements crossing endodermis through passage cells. In non-living spaces (apoplast) movement is by diffusion.

Ascent of sap

Synopsis

- Ascent of sap is upward movement of water against gravitational force in the plants.
- Water moves in the xylem. It can be proved by girdling or ringing experiments.
- Theory of ascent of sap proposed by Henry Dixon.Theory called Cohesion –Tension theory.
- A basic element of theory is Transpirational pull, Cohesion of water molecules (approximately 30 Mpa) and adhesion of water molecules with the walls of xylem vessels and tracheids.
- Due to transpiration mesophyll cells loose water results in decrease in water potential of mesophyll cells.
- Water moves into mesophyll cells. This gradient extends into xylem resulting in tension in xylem.
- Water ascends into the xylem from roots as unbroken water column.
- An estimated 1.3Mpa water potential gradient is needed for water to raise 400 feet with an optimum velocity.
- Water movement to the top of the plants like *Eucalyptus amygdalina* (143 m) and *Pseudotsuga manziesii* (119.8m) with this water potential gradient is possible.
- Objection of embolism (cavitation) in large xylem vessels during high transpiration can be explained by the presence of pits in lateral walls of the vessels.
- According to this theory tracheids are more efficient than vessels in conducting water due to their narrow size.

Transpiration

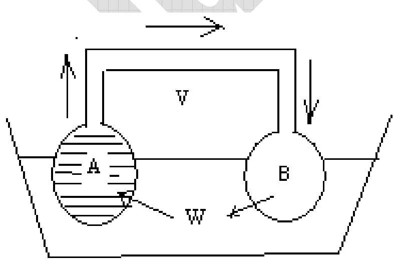
Synopsis

- Less than 1% of water absorbed by the terrestrial plants is used in metabolic reactions.
- 99% of water absorbed by the roots is lost by transpiration from leaves.
- The ratio of transpirational loss of water by a plant to its dry matter production in a growing season is the tranpirational ratio.
- Water absorbed from the soil raises to the leaves and lost to the atmosphere. This continuity of water is called SPAC.Soil Plant Atmospheric Continuum.
- Maximum transpiration(80-95%) occurs through stomata. Least (1-2%) from lenticels. Cuticle looses around 5-10%.
- Tranpiration in plants can be demonstrated by Bell jar experiment. Transpirational rates can be measured by Ganongs photometer method or cobalt chloride method. Blue colour dry cobalt chloride changes to pink when exposed to moisture.
- Size of the stomatal aperture is one of the parameter for the transpirational rates.
- Stomatal pore is guarded by two guard cells. The turgidity of the guard cells decreases the pore size.
- Generally stomata open during day times (photoactive stomata). In CAM plants they open during night time.
- Stomatal movements are closely associated with metabolic changes of the guard cells. Guard cells have full complement of cell organelles including chloroplast. Chloroplasts are absent in other epidermal cells.
- Stach occumulate during night time unlike other photosynthetic mesophyll cells.
- Stomatal movements can be explained by K^+ pump hypothesis proposed by Levitt.
- According to this hypothesis during stomatal opening starch converted into malic acid which dissociate into malate ions and H^+ ions in guard cells.
- Active movement of protons outside the guard cells results in excessive influx of K^+ ion which are balanced by the inward movement of Cl^- ions.
- This results in the lowering of water potential of guard cell that result in water movement into guard cells causing turgidity of the guard cells.
- During closure reversal of these changes take place.ABA – a plant hormone changes permeability of plasma membrane assisting the outward movement of K^+ and Cl^- ions.
- Factors like light, atmospheric humidity, temperature wind increases the rate of transpiration.
- Internal factors like anatomical features like thick epidermis , cuticle, etc influences the rate of transpiration.
- Surface area, distribution of stomata , number of stomata, root shoot ratio lso influences transpiration. Rate of transpiration increases with an increase in root shoot ratio.
- F.A. Salisbury introduced Stomatal Index for stomatal frequency. I= S/E+S. (I= stomatal index: S= No of stomata per unit area: E= No of epidermal cells in the same unit area.
- Helen Curtis regarded transpiration as “necessary evil” and Barnes was of the opinion as an “unavoidable evil”.
- Phenyl mercuric acetate (a fungicide), abscisic acid and aspirin can act as antitranspirants besids substances like waxes, silicon oils, plastic emulsions.

TRANSLOCATION OF SUGARS

Synopsis

- Generally sucrose is the transported sugar in the phloem.
- From the site of the synthesis in the cytoplasm of chlorophyllous cells into the xylem crossing several cells is called as phloem loading.
- It crosses plasma membrane of green cells into the apoplast (cell wall) and enters into phloem crossing single or many cells.
- The direction of the movement is mostly downward. Upward movement from leaves to fruits. In cereals flag leaf (first leaf below the inflorescence) supplies 50% 0f carbons to the growing grains.
- Movement of sugars occurs in the sieve elements (sieve tubes).
- Rates of transportation ranges from 50 to 100 cm/h. It is much faster than diffusion of sugar molecules through water.
- Regions supplying sugars is known as sources. Regions that utilize transported sugars in the phloem are known as sinks.
- Besides sucrose some transport raffinose, stachyose and verbascose sugars.
- Concentration of sugars depends on rate of photosynthesis.
- Transportation in the plants can be demonstrated ringing or girdling experiment or making incision if the bark and using autoradiograph.
- It is measured with potometers.
- Several theories were proposed regarding the mechanism of translocation.
- Pressure flow or mass flow hypothesis was proposed by Munch



- The two containers A(source) and B(sink) are fitted with membranes that are permeable to water W but not to sugar solution. At the start of the demonstration, A is filled with a 10 to 15% solution with a dye and B with water. Both A and B immersed in water. Water will move by osmosis from W to A. As a result, the hydrostatic pressure in A becomes higher than in B. This hydrostatic pressure differences between A and B provides the driving force for the movement of coloured solution through glass tube V into B and for the diffusion of water through the membrane out of B.
- The pressure flow hypothesis visualizes a steady, unidirectional, osmotically generated flow of sugar solution through living sieve elements.