ASCENT OF SAP

Definition:

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 as Ascent of Sap.

Ascent of sap can be studied under the following two heads:

(A) Path of Ascent of Sap, and

(B) Mechanism of Ascent of Sap.

(A) Path of Ascent of Sap:

It is well established that the ascent of sap takes place through xylem.

Experiment:

A leafy twig of balsam plant (it has semi- transparent stem) is cut under water (to avoid entry of air-bubbles through the cut end) and placed in a beaker containing water with some eosin (a dye) dissolved in it. After sometime coloured lines will be seen moving upward in the stem. If sections of stem are cut at this time, only the xylem elements will appear to be filled with coloured water.

(B) Mechanism of Ascent of Sap:

In small trees and herbaceous plants the ascent of sap can be explained easily, but in tall trees like Australian Eucalyptus, some conifers such as mighty Sequoias (Sequoia, Sequoia Dendron,

Metasequoia are the tallest and thickest trees of the present day flora, sometimes reaching a height of 300-400′) where the water has to rise up to the height of several hundred feet, the ascent of sap, in fact, becomes a problem. Although the mechanism of ascent of sap is not well understood, a number of theories have been put forward to explain it.

Theories of Ascent of SAP:

(A) Vital Theories:

Supporters of vital theories think that the ascent of sap is under the control of vital activities in the stem.

According to Godlewski (1884) ascent of sap takes place due to the pumping activity of the cells of xylem parenchyma which are living. The cells of the medullary rays which are also living, in some way change their O.P. When their O.P. becomes high they draw water from the lower vessel and their O.P. becomes low. Now due to the low O.P., water from the cells of xylem parenchyma is pumped into the above vessel. This process is repeated again and again and water rises upward in the xylem.

This theory seemed only hypothetical, and was further discarded by the experiments of Strasburger. (1891, 1893) who demonstrated that ascent of sap continues even in the stems in which living cells have been killed by the uptake of poisons.

(B) Root Pressure Theory:

Root pressure which is developed in the xylem of the roots can raise water to a certain height but it does not seem to be an effective force in ascent of sap due to the following reasons:

(i) Magnitude of root pressure is very low (about 2 atms).

(ii) Even in the absence of root pressure, absent of sap continues. For example, when a leafy twig is cut under water and placed in a beaker full of water it remains fresh and green for sufficient long time.

(iii) In gymnosperms root pressure has rarely been observed.

(C) Physical Force Theories:

Various physical forces may be involved in the ascent of sap:—

(1) Atmospheric Pressure:

This does not seem to be convincing because:

(i) It cannot act on water present in xylem in roots,

(ii) In case it is working, then also it will not be able to raise water beyond 34′.

(2) Imbibition:

Sachs (1878) supported the view that ascent of sap could take place by imbibition through the walls of xylem. Now it is well known that imbibitional force is insignificant in the ascent of sap because it takes place through the lumen of xylem elements and not through walls.

(3) Capillary Force:

In plants the xylem vessels are placed one above the other forming a sort of continuous channel which can be compared with long capillary tubes and it was thought that as water rises in capillary tube due to capillary force, in the same manner ascent of sap takes place in xylem.

There are many objections to this theory:

(i) For capillarity a free surface is required.

(ii) The magnitude of capillary force is low.

(iii) In spring when there is more requirement of water due to the development of new leaves, the wood consists of broader elements. While in autumn, when water supply decreases, the wood consists of narrow elements. This is against capillarity.

(iv) In Gymnosperms usually the vessels are absent. Other xylem elements do not form continuous channels.

(D) Transpiration Pull and Cohesion of Water Theory:

This theory was originally proposed by Dixon and Joly (1894) and greatly supported and elaborated by Dixon (1914, 1924). This theory is very convincing and has now been widely supported by many workers.

Theory of Cohesive Force:

Of all the theories given for the ascent of sap (vital and physical force theories), this theory is most widely accepted & advanced because:

(i) It gives most satisfactory explanation of the process as per the need of the plant.

(ii) It is based on known facts.

(iii) It explains the mechanism on the basis of such physical forces, which actually exist in plants. Therefore, the theory has a sound base.

It is explained on the basis of following facts and physical forces:

(a) Water is conducted through the lumen of xylem vessels and tracheid's,

(b) It is based on known facts.

(c) It explains the mechanism on the basis of such physical forces, which actually exist in plants.

Physical Forces:

(i) Force of Cohesion:

Molecules of water in the xylem are held together because of great cohesive force (up to 350 atmosphere) of attraction between them. This helps to maintain continuity of water column.

(ii) Force of Adhesion:

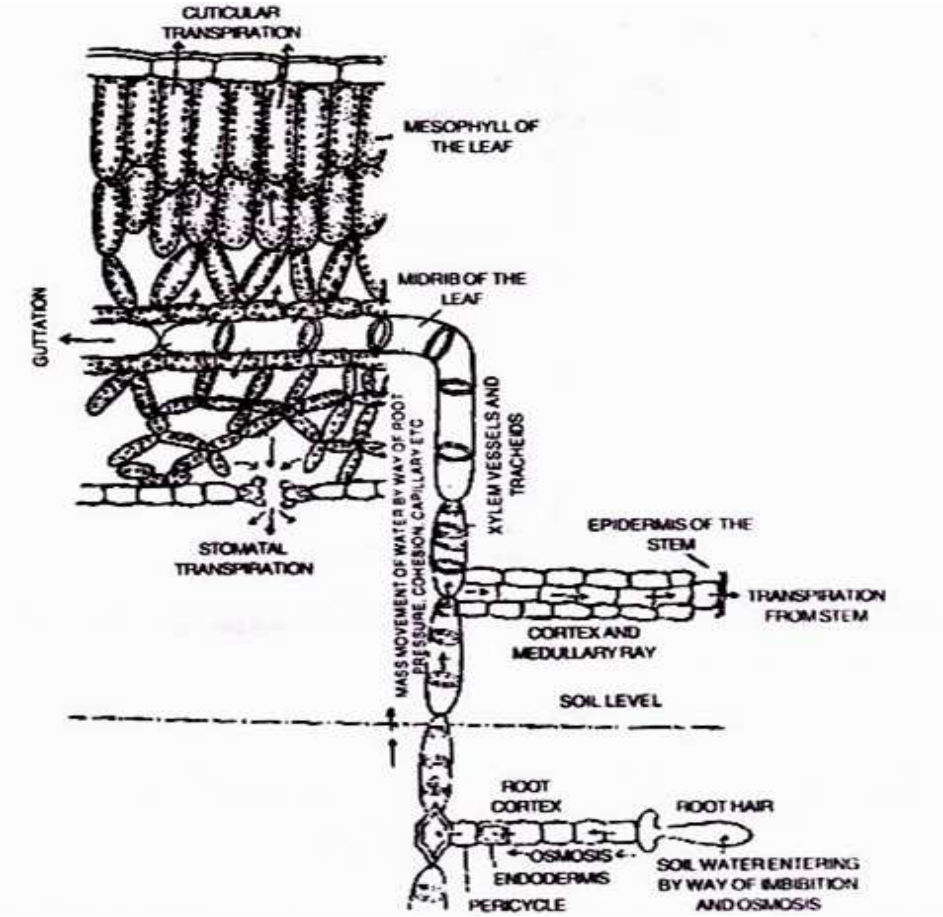
There is attraction (adhesion) between the water column and walls of xylem. This prevents accumulation of air blocks in xylem and also prevents break in water column.

(iii) Suction Force (Transpiration Pull):

The water deficit or suction force developed in leaf cells due to transpiration is responsible for pulling the water column in the upward direction (ascent of sap) .

Hence, it is called transpiration pull. The magnitude of suction force is sufficient to lift the water column to any heights, even in tallest trees.

However, it is not enough to break the continuity of water column. Thus, greater the transpiration, greater is the transpiration pull (suction force) and hence higher the rate of ascent of sap. Similarly, when transpiration is low, the suction force (transpiration pull) is also low and hence the rate of ascent of sap is also lower.



Significance and Role of Transpiration Pull:

(i) It helps in ascent of sap.

(ii) It is responsible for absorption of major quantity of water by roots by way of passive mechanism without requiring energy in the form of ATP.

(iii) Transpiration pull initiates the large scale movement of water form soil into root xylem and then upwards to all aerial parts (ascent of sap).

Evidences in Support of Theory:

(i) The amount of water transpired is equal to the amount of water absorbed.

(ii) Upward movement of water continues even when cut shoots (from below) are placed in water.

(iii) Cohesive force that holds the water molecules in a column as narrow as xylem vessels is very strong and they withstand the opposing transpiration and gravitational pulls.

(iv) Because of the opposing forces, tension develops in the water column. As a result, xylem elements become slightly narrow. This results in the contraction and expansion of the stem which has been demonstrated by using dendrometer. The diurnal behavior of rhythmic contraction and expansion is a good evidence for the water column to be in tension which the transpiration is rapid or not.

(v) The forces that operate cohesion transpiration pull are just passive forces and no metabolic energy is involved in this phenomenon, because present the movement of water upwards.

Objections against Cohesion Theory:

(i) A serious objection generally raised against this theory is that the air dissolved in the sap shall form bubbles under tension and high temperature. The introduction of such air bubbles in xylem would break the continuity of water column and thereby stop ascent of sap due to transpiration pull. This objection was, however, dismissed by Scholander et. al. (1957) who proposed that the continuity of water column is maintained because of the presence of pits in the lateral walls of xylem vessels.

(ii) Nobody has yet devised a method of measuring the tension in the xylem of an intact plant. Until the existence of substantial tension has been confirmed by direct measurement, the cohesion theory would remain just a theory.

It is based on the following features:

(i) Cohesive and Adhesive properties of water molecules to form a continuous water column in the xylem.

(ii) Transpiration pull exerted on this water column.

PROBABLE QUESTIONS :

1. **Define Ascent of SAP**
2. **Mention the theories regarding Ascent of SAP**

3. Mention Jolly Dixon theory regarding Ascent of SAP

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