

Chapter - 6

Water Absorption and Ascent of Sap in Plants

Water absorption and pathway of water in plants

Water is the major component of cells all living and all is essential for biological activities, Gas, minerals and many organic compound are soluble in water. Therefore these substances are absorbed and distributed in the form of aqueous solution by plants. The water requirement of plants is fulfills from soil water and the main source of water for the soil is rain. After heavy rain, most of water flows through the surface of the earth and reach to the ponds, ocean which is called run away water. But in light rain, most of the water is absorbed in the soil which is called soil water. Soil water is also of many types like capillary water, gravitational water hygroscopic water etc. Out of these, capillary water is readily available to the plant.

Water absorbing organs of plant -

There are no special organs for water absorption in lower plants such as algae & fungi. All cells in their plant body absorb water and mineral salts. Bryophytes have rhizoids for water absorption. While higher plants have well developed root system. Water and mineral salts are not absorbed from the whole surface of roots. Root has two parts (region) : (i) young region (ii) region of maturation.

Water absorption occurs in the young region of root because due to the lignification and suberization in cells of region of maturation, their walls are impermeable to water. The young region of the root can be divided into five parts.

(i) Root Cap :- This is the terminal part of the root which provide a protective layer to the root's growing tips.

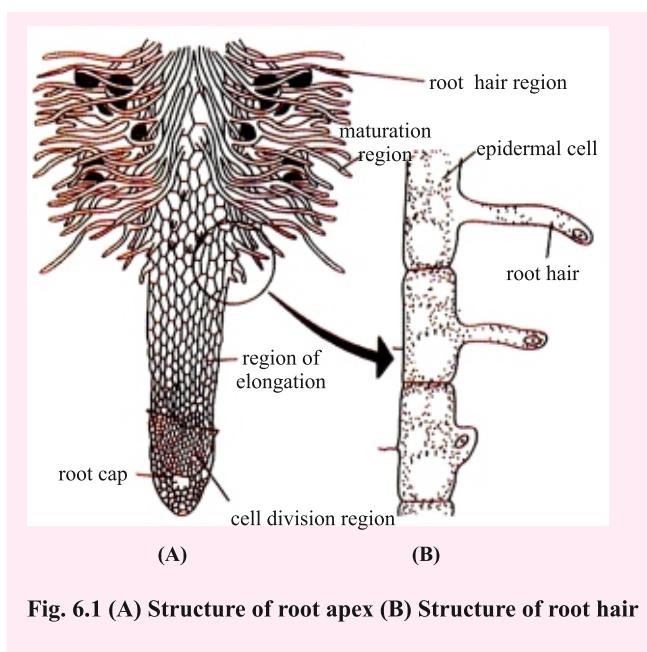


Fig. 6.1 (A) Structure of root apex (B) Structure of root hair

(ii) Root apex : This is the subterminal area of the root whose cells are meristematic or divisible. This is called as zone of cell division. This region is responsible for the growth of root.

(iii) Region of elongation : This is the back part of root apex. There are thousand of root hairs in this area. This part of the root is mainly important for water absorption.

(iv) Region of maturation : It is the mature part of the root which carries out less water absorption due to the lignification and suberization

of cells.

Mechanism of water absorption

According to the Kramer, 1949 water absorption occurs by two type :

1. Passive absorption of water
2. Active absorption of water

When the factors for water absorption are located in the transpiring surface that is present in the leaves and the cells of the root function only as the passage, then it is called as passive water absorption. Contrary to this, when the absorption factors are present in the root and the cells of the root take active part in the absorption then it is called as active water absorption. In other words, the forces for passive absorption originate in the aerial part or in the stem of plant, whereas for active absorption the origin of force is in root. Therefore, the role of the root in passive absorption is subsidiary. While, in active absorption the root plays the main role.

Mechanism of passive water absorption

It is the main method of water absorption in plants. 96% to 98% of water absorbed by most of the plants is done by this method in the form of transpiration. Due to the loss of water, from the aerial parts of plants mainly leaves, a stress or pull is developed in its veins. This negative stress reaches to the roots through the stem water column, respectively. By which water is pulled up from the soil by root hairs to the roots. Thus, no part of the plant has an active role in passive absorption. The biggest evidence in favour of this principle is that the process of water absorption is also very high transpiration.

Mechanism of active water absorption

In some plants, the absorption of water in small amounts is caused by the activity of roots or the positive forces generated in the roots. This process mostly happens when the transpiration is very low or negligible like in night. Thus, the roots have a major role in active water absorption. For this absorption, the positive force is generated in the water column present in the xylem in the root which is called root pressure. By this force like OP, the roots forcefully pull the soil water or absorb it.

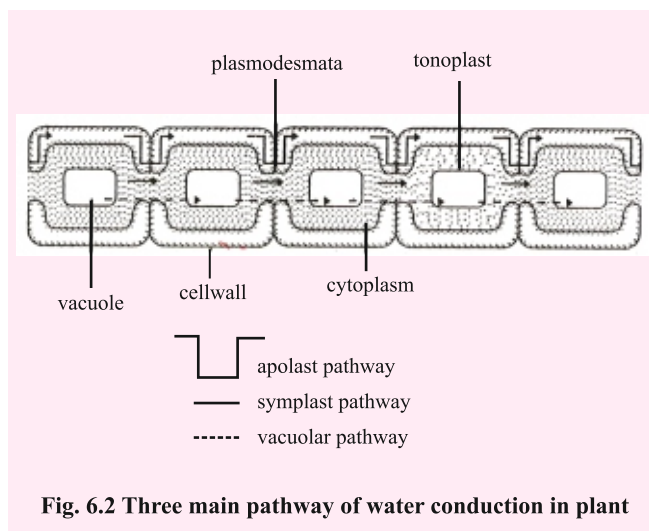
Active water absorption requires energy in the form of ATP which is provided by the respiratory cells of the roots. By this method the absorption of water is significantly reduced i.e. the amount of absorbed water is 2-4% of the total absorbed water.

Pathway of water in plant

After the entry of water in plants, from the root hair, it can reach to xylem within the roots mainly by three following pathways. The flow of water from the root hair to xylem is called lateral flow.

- (i) Apoplast pathway
- (ii) Symplast pathway
- (iii) Vacuolar pathway

(i) Apoplast pathway :- The flow of water in plants is through non-living cell walls and intercellular spaces present in the cells. So, this route is called apoplast pathway. This flow of water is uncontrolled and through diffusion. Casparian strips are found in the cell wall of endodermis of roots in the plants, in which suberin is present. Suberin is impermeable towards water. Therefore, flow of water by this pathway can not be through endodermis. The flow of water from endodermis cells is done by their cell membrane. The path of water is called transmembrane pathway.



(ii) Symplast pathway : When the water is transmitted from one cell to the other cell through plasmodesmata (by protoplasm). Then this kind of flow path is called symplast pathway. This type of

flow is done by the action of osmosis and requires energy. This path is also called living path. This path shows maximum resistance.

(iii) Vacuolar pathway : In this type of flow the water enters from one cell to the other cell through plasma membrane not by plasmodesmata. After this the water passes through the tonoplast and the vacuole. This process is also done by osmosis and it requires energy.

Factors affecting water absorption

Water absorption mainly passive water absorption is influenced by the following factors.

1. Available soil water : All types of water present in the soil are not available for plants. Mainly a part of the cell water is only accessible. The most ideal condition for normal water absorption is that the water in the soil is well under its field capacity or water holding capacity and permanent. The amount of water remaining in the soil even after the excess water is expelled from the soil by gravitational force is called water holding capacity or field capacity.

Permanent wilting percentage is the percentage of the soil water, when the leaves of the grown plant show permanent wilting for the first time. This situation is called permanent wilting percentage.

2. Soil aeration : There is sufficient water absorption from well aerated soil like loam soil. Low and zero water absorption is in non-aerated soil.

3. Soil temperature : The optimum temperature of soil where maximum water is absorbed lies between 20° to 30°C. At temperature less than 20°C and more than 30° C absorption starts decreasing.

4. Concentration of soil solution : Due to the abundance of mineral salts in soil the concentration of soil solution is high. In this situation water absorption is minimal. Compared to this, in dilute soils solution water absorption is high.

ASCENT OF SAP

Water from the soil is absorbed by the root hair

which reaches to the top of the plants and in other organs in the form of dilute solution. The upward transfer of this water is called ascent of sap.

The transfer of water in plants is done by the xylem elements especially vessels and tracheids, which can be demonstrated from the experiment shown below.

Path of ascent sap

Experiment : Cut the roots of the balsam plant and immerses it in the solution of saffranin for two or more hours. Saffranin is a reddish stain that only stain the lignified tissue. (xylem, sclermchyma). After 2 hours, the veins of the leaves of Balsam start appearing red. In this stage, transverse section of the leaf, petiole of leaf or branch is seen under the microscope, the red color of saffranin visible in the xylem ducts. Therefore, it is clear from this experiment that ascent of sap is done only by the xylem tissues in the plant.

Mechanism of Ascent of sap

Various theories have been presented to explain the mechanism of rising of water in trees against gravitational force during ascent of sap. They have been categorised in three class -

1. Vital force theories
2. Root pressure theories
3. Physical force theories

1. Vital force theories

According to these principles, the ascent of sap in plants occurs by biological forces generated due to the activities occurring in living cells of the stem. In this regard the idea of major scientists have been summarized. According to Goldewski's Relay pump principle (1884)

Xylem parenchyma and medullary rays show recurring changes in the osmotic pressure of the living cells of stem due to which the action of ascent of sap occurs.

According to the pulsation principle of sir J.C. Bose (1923), ascent of sap occurs due to the regular rhythmic pulsation in the cells of the inner layer of the stem cell of the cortex that are in contact with the endodermis. He carried out his experiments on

Indian telegraph plant (*Desmodium gyrans*).

According to Strasburger (1891) living cells are not directly related to the mechanism of ascent of sap. But their presence is necessary to create a favourable atmosphere for this action.

2. Root pressure theory

Cell wall of the parenchyma cells is of flexible nature. These cells undergo tension in the cell wall from the entry of water or solution in it and it again tries to come back to its normal position. In this process, a positive pressure develops on the matter in the cell. As a result, some quantity of liquid comes out from the cell and moves into the vessels. Due to this liquid, the pressure generated in the vessel elements is called root pressure. In other words, positive pressure present in sap of xylem vessels is called root pressure.

The original pressure is measured by manometer. But in any plant it can not get more than 2 atmosphere. 2 atmospheric pressure is sufficient for plants to raise water up to about 20 meters high. But 12 atm pressure is required for higher woody plants. So much of the root pressure in any plant has never been seen under any circumstances. So this principle is of limited importance. Also the root pressure is not found in all the plants. The root

pressure is not found in any gymnosperm plant.

3. Physical Force Theories

According to these principles, ascent of sap is due to physical forces only and living cells do not participate in it. Scientists have repeatedly told that many forces are responsible for the ascent of sap, which includes atmospheric pressure, imbibition and capillary. The most prominent is Dixon and Jolly's (1894) principle, according to which cohesion tension of water and transpiration pull are the most valid for all theories. Following are the few major features of Dixon & Jolly's cohesion tension principle or transpiration pull-

- (i) There is a continued column of water in plants from root to leaf. This is called water static system.
- (ii) Water loss by transpiration causes a pull in the water column of the veins of the leaf. This pull is called pull transpiration pull.
- (iii) Water molecules have cohesive force which can reach up to 45-207 atmospheres. Due to this force, column of water does not break due to transpiration instead it is pulled towards upper side.
- (iv) Thus according to Dixon and Jolly's theory, due to the stress generated by transpiration and cohesive force between water molecules, water is pulled passively from the base to the apex. Neither any metabolic energy consumption is involved in this work nor any contribution of living cells. Ascent of sap is completely operated by physical forces.
- (v) Many evidences have been given in support of this principle, like the rate of transpiration is directly related to ascent of sap, during day time the water column in stem and branches of the plant is in the stressed position etc.

At present, this principle is most valid in understanding the process of ascent of sap.

Important Points

1. The root hair area of the plants root absorbs water from the soil.
2. The flow of water from the root hair to the

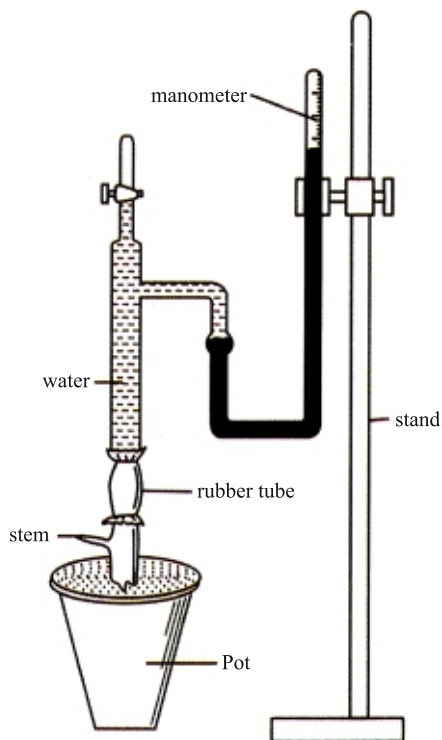


Fig. 6.3 Demonstration of root pressure in plant

xylem of the root is called lateral flow.

3. The absorption of water in the plants is by two processes i.e. passive and active absorption.
4. Lateral flow of water occurs by three pathways such as apoplast, symplast and vacuolar pathway.
5. The required force for passive absorption is generated by the transpiration from the aerial part of the plant. This is a physical process the plant's metabolic energy is not consumed in it. This is the main process of water absorption.
6. Active water absorption is not of special importance. In this process energy of plant is consumed in the form of ATP
7. Many factors affect water absorption . The main factor are available soil water soil aeration, soil temperature, and concentration of soil solution.
8. In upward movement of absorbed water from the root to the tip apex of the plant through the stem against gravitational force is called ascent of sap.
9. Ascent of sap occurs due to tracheids & vessels of stem.
10. Dixon & Jolly have presented the most valid principle regarding ascent of sap it is called transpiration pull and cohesive tension principle.

Practice Questions

Multiple choice questions-

1. Accessible water to the plant from the soil is -
(A) Capillary water
(B) Flowing water
(C) Hygroscopic water
(D) Gravitational water
2. Which part of the root absorbs water -
(A) Root apex
(B) Region of elongation
(C) Root hair region

(D) Maturation region

3. What is the most resistant way for water absorbed in plants to reach the xylem -
(A) Apoplast
(B) Symplast
(C) Membrane pathway
(D) Vacuolar pathway
4. Who presented the cohesion principle -
(A) Godlewski
(B) J.C. Bose
(C) Strasburger
(D) Dixon & Jolly
5. Which tissue is responsible for upward movement of the water during the ascent of sap in the plant -
(A) Cortex
(B) Vessels
(C) Tracheids
(D) Vessels & Tracheids

Very short answer questions-

1. Name the different routes of lateral water flow.
2. What is capillary water?
3. What is root hair?
4. Which plant did J.C. Bose work on?
5. Name the principle of Dixon & Jolly.

Short answer questions-

1. Make a diagram for pathways of lateral water flow.
2. Mention the difference parts of the root while describing the organ for the water absorption.
3. Describe the active method of water absorption.
4. Highlight any two factors affecting water absorption.
5. Define Ascent of sap.
6. The principle presented in relation to ascent of

sap is divided into how many classes? Write them.

Essay type questions-

1. Write a summarised note article on the on the process of water absorption by plants.
2. Describe the process of ascent of sap in trees in detail.

Answer Key-

(1)(A) (2)C (3)(B) (4)D (5)D