Chapter - 7
Transpiration

Plants absorb water from the soil and transmit it to various organs by ascent of sap. The amount of water absorbed by plants is much higher than its own requirement. Plants use some amount of water absorbed in their metabolic activities, while the remaining water is liberated in the form of vapour. The process of liberation of the water from different aerial organs of the plants in water vapour form is called transpiration.

Types of Transpiration

Transpiration may occur from any part of the plant other than root system. There are three types of transpiration :-

1. Stomatal transpiration :- Leaves are the major organ of transpiration. Stomata are present on the surface of the leaves which cause stomatal transpiration. This accounts for about 50-97% of total transpiration.

2. Cuticular transpiration :- Leaves of most xerophytic plants are covered by the cuticle. Generally cuticle is impermeable to water. At some places it is very thin or broken, from where there is a small amount of loss in vapour form. This type of transpiration is known as cuticular transpiration. It accounts for 3 to 10 % of the total transpiration.

3. Lenticular transpiration :- Woody stem and some fruits have small pores on the surface, called lenticels. In some environmental condition water vapours comes out from lenticels which is called lenticular transpiration. This is only 1% of total transpiration.

As it is clear from the above description, most of the transpiration occurs through stomata present in the plants. So here we will carry out a detailed study of the stomatal transpiration.

Stomatal Transpiration

To understand the stomatal transpiration, we have to understand the structure of leaf and stoma. The upper and lower surface of leaf is called epidermis. Mesophyll tissue is situated in between both epidermis. In the dicot leaves, it is differentiated into palisade and spongy paranchyma.

The presence of stomata is the main feature of epidermis. Stomata are found on one or both surfaces of leaf. On the basis of their presence, the leaves are of three types.

(i) Hypostomatic :- When the stomata are restricted only to the lower surface of the leaf. Such leaves are called hypostomatic. Ex. apple, orange

This type of leaf is also called apple type. Leaves of most of the dicot plants are hypostomatic.

(ii) Amphistomatic :- When stomata are present on both surfaces of leaf, such leaves are called Amphistomatic. Ex. Maize, oat & all other grasses. This type of leaf is also called oat type. Leaves of most of the monocot plants are amhistomatic. The number of stomata on both surface is almost the same.

(iii) Epistomatic :- When stomata are present on upper surface only such leaves are called

epistomatic. Ex. water lily and other floating plants. It is also called lily type. In most of the floating hydrophytes the leaves are epistomatic.

Structure of Stoma

In most of the plants, each stomata is composed of two bean shaped cells known as guard cells. Guard cell are arranged in such a way that a pore is formed between them which is called stomatal pore. The inner wall of guard cells is highly thickened toward the stomatal pore and the outer wall of guard cells is thin. Because of which when the guard cells are turgid, the stomata opens and when the guard cells are flaccid, the stomata closes.

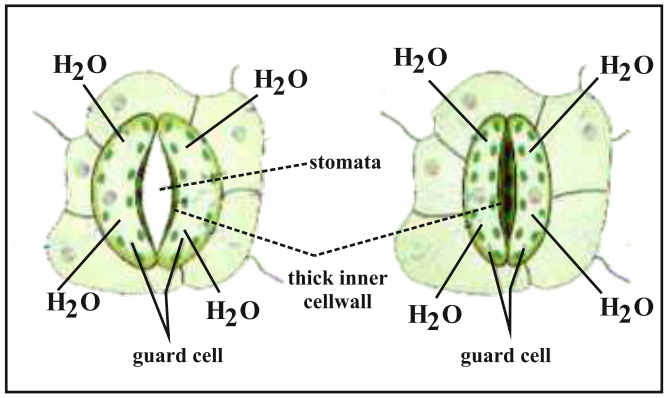

Fig. 7.1 Stomatal apparatus (A) Open stomata (B) Close stomata

In the turgid position, the outer thin wall of guard cells expand and stretches to the outer side. This pulls out the inner thick wall open the stomata. In case of a flaccid position, the guard cells come back to the previous state and closes the stomata. Cells present around the guard cells are different from the other epidermal cells. These cells are known as subsidiary cells. The leaves have 100 to 60000 stomata per square cm.

Mechanism of stomatal movement

The process of opening and closing of stoma is called stomatal movement. Several hypothesis have been presented in this content:

1. Starch sugar hypothesis

J.D. Sayre, 1923 proposed this opinion. According to which, in light (day time) CO_2 decreases in the guard cell these by increasing the pH. Phosphorylase enzyme gets is activated in the cells at high pH. As a result starch changes in glucose - 1 phosphate which increases the DPD of the guard cell which become turgid and stomata opens. The increase in CO_2 in the guard cell in the dark (in night) turns their pH acidic. By which glucose - 1- phosphate converts in to starch again. As a result guard cells get flaccid and stomata closes. Before Sayre (1926) Loyed (1908) told that starch is present in guard cells.

2. Steward's hypothesis

Steward justified the hypothesis of the Sayre and explained at high pH starch is further analyzed Glucose - 1- phosphate where by respectively Glucose -6- phosphate is formed and at last glucose is formed. Glucose -6- phosphate and glucoseare more soluble in water than glucose -1- phosphate. Therefore, the concentration of the guard cells increases that is sufficient for the opening of stomata.

3. Active potassium ion transport theory

This theory was enumerated by Japanese scientists Emamura & Fugino in 1959 and Levit (1974) modified it which is currently the most valid theory. According to this theory, Malic Acid formed in guard cells during light (in day) dissociates into Malate and H^+ ion. Potassium ions enter guard cells from the adjacent cells and H^+ exists from guard cells. Potassium ion reacts with malate to form potassium malate, flows which increases the concentration of the guard cells. So the water flows is in the guard cells, by which the guard cells become turgid and stomata opens. There is no photosynthesis at night (in dark), so CO_2 concentration, increases in the guard cell. Malic acid changes into starch where by the osmotic concentration of the guard cells decreases. Water flows out due to the exosmosis and guard cells become flaccid; because of this, stomata closes.

In day time

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Formation of malic acid in guard cell

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Dissociation of malic acid

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malate + H^+

↓

Entry of K^+ ion subsidiary cells to guard cells by active transport and exist of ions exit of H^+ ions.

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Potassium malate

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Increase in concentration of guard cells

↓

Guard cell become turgid due to endossmosis

↓

stomata open

In night time

↓

The concentration of CO_2 increases in substomatal cavity, as photosynthesis stops

↓

Activation of Abscisic Acid in presence of Co_2

↓

Exit of K^+ ion from guard cells

↓

Decrease in the osmotic concentration of guard cells, exosmosis

↓

Guard cell become flaccid

↓

stomata closes

Factors affecting transpiration

The process of transpiration is influenced by many factors which can be divided into two types

I. External factors

II. Internal factors

I. External factors

1. Light :- Light affects transpiration in both direct and indirect ways. Presence of light causes openings of stomata in direct way and indirectly it increases the rate of transpiration by increasing the temperature.

2. Wind :- With the rapid flow of air the moist air around the leaf is removed and dry air comes in contact with leaf. As a result of rapid wind flow, transpiration is higher.

3. Available soil water :- The rate of transpiration depends on the available soil water. Due to lack of available soil water, the rate of transpiration decreases.

4. Temperature :- As the temperature increases the relative humidity of the atmosphere decreases and so the rate of transpiration is high.

II. Internal factors

i. Leaf structure :- The rate of transpiration is influenced by the structure of the leaf. Epidermis of leaves of xerophytic plant are covered by cuticle, wax and hairs and stomata are sunken. This characterstic reduces the rate of transpiration.

Number of stomata (frequency) in the unit area of leaf is also an unimprotant factor.

ii. Root - shoot ratio : - Transpiration also increases in plant with an increase in the root shoot ratio.

iii. Leaf orientation :- If the orientation of the leaves is at right angles of incident radiation so the sun's ray have the most effect on them and the transpiration rate is high. But, if the orientations of the leaves is parallel to the incident radiation, then the transpiration rate is low.

Significance of transpiration

According to the scientists view, the transpiration is the necessary evil which is useful for plants but sometimes harmful too. Benefits of transpiration to the plants are as following :

I. Ascent of sap in plants is due to transpiration pull.

ii. The absorption and transfer of water and minerals in plant is by transpiration

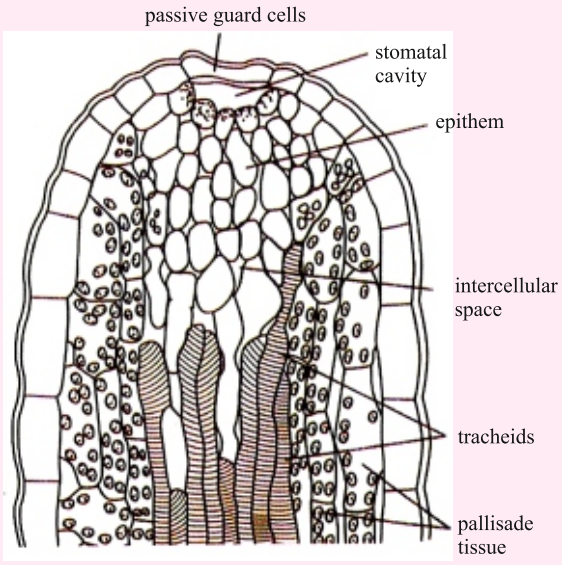
iii. Transpiration also reduce the temperature of leaf.

iv. Release of excessive water.

Guttation

Secretion of water in the form of small droplet from margins of leaves is called guttation. In the morning guttation is clearly visible in the leaves of plant like Potato, Arabi, Bryophyllum & some grasses.

(A)



(B)

Fig. 7.2 (A) Droplet by guttation on leaf margin (B) Structure of hydathode

The loss of water is from the small pores located at the end of the leaf vein which are called hydathodes. At the top of each hydathode, there is a hole called water pore. There is no movement in the cells present around water pore, it always remains open. There is a group of parenchymatous cells towards the inner side hydathodes which is called epithem tissue. The epithem is connected to the xylem vessels of the veins of leaf towards the inner side. Hight absorption of water by the root and low transpiration generates a root pressure in the xylem vessels due to which the water comes out of the xylem vessels and is transmitted to the epithem cells. When these cells are saturated, the water comes out from the pores in the form of droplet. So, guttation is due to the root pressure.

The water released in the guttation is not pure, instead some inorganic and organic salts are dissolved in it.

Bleeding

Oozing of sap from the cut or damaged part of the plant is called bleeding. Sap of xylem vessels of plants remains in positive stress due to root pressure. When xylem vessels are cut or damaged, it leaks out. This type of leakage from rubber tree is also called latex, from which rubber is made.

Important Points

1. Transpiration is the loss of water in the form of vapour from the aerial parts of plant.
2. Transpiration is of three types - stomatal, cuticular and lenticular transpiration.
3. Stomatal transpiration is the main method of water loss. This action occurs from stomata present on leaves.
4. Stomata are composed of two guard cells. These cells are often kidney shaped.
5. The principle of active potassium ions in relation to stomatal movement is most valid.
6. Transpiration is affected by many external factors like light, wind, temperature and internal factors like structure of leaf, root to shoot ratio and leaf orientation.
7. Transpiration is both beneficial and harmful to plants.

8. Loss of water in form of liquid from hydthodes present on leaf margins is called guttation.

Practice Question

Multiple Choice Questions-

1. Which of the following part show does not transpiration -

   (A) Leaf (B) Stem

   (C) Root (D) Raw fruits

2. The maximum amount of transpiration occurs-

   (A) From stomata

   (B) From lenticels

   (C) From Hydathodes

   (D) From all

3. Hydathodes are found :

   (A) On leaf margin

   (B) Upper surfce of leaf

   (C) Lower surface of leaf

   (D) In bark

4. In plants, the fluid liberated during the activity of guttation is -

   (A) Pure water

   (B) Waste only

   (C) Water and Co_2

   (D) Organic and Inorganic substance with water

Very short answer questions-

1. What are the various types of transpiration? Name them.
2. Maximum transpiration occurs by which action?
3. What is the shape of guard cells?
4. Who introduced the active potassium ion theory
5. Explain one of the benefits of transpiration
6. What is the status of guard cells at the time of opening of stomata?

Short answer questions-

1. Define transpiration.
2. Define guttation.
3. Draw a labelled diagram of stomatal apparatus.
4. Describe an external factor affecting transpiration

Essay type Questions-

1. Describe the various types of transpiration.
2. Explain the mechanism for opening and closing of stomata.
3. Discuss a valid theory related to stomatal movement.
4. "Transpiration is a neccessary evil." Explain this statement.
5. Describe the factors affecting transpiration
6. Write a detailed comment on guttation.

Answer Key-

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