Transport in Plants - Part 3

Objectives

After going through this lesson, the learners will be able to understand the following:

- Structure of phloem, role of phloem in translocation of sugars synthesised by photosynthesis
- Direction of transport, concept of source and sink
- Nature of the sugars and other organic matter translocated in the phloem
- Phloem loading and unloading
- Mechanism of phloem translocation – role of bulk transport

Content Outline

- Introduction
- Direction of translocation – source - sink concept
- Nature of substances translocated in the phloem
- Phloem loading - transport of sugars from source cells to the phloem
- Translocation in the phloem by bulk flow
- Phloem unloading - transport of sugars from phloem to sink cells
- Concluding remarks
- Summary

Introduction

In this module, we will discuss the transport of photos – assimilates to all parts of a plant. The translocation of sugars synthesized by photosynthesis takes place in the phloem. So to understand the process we must first understand the structure of the phloem.

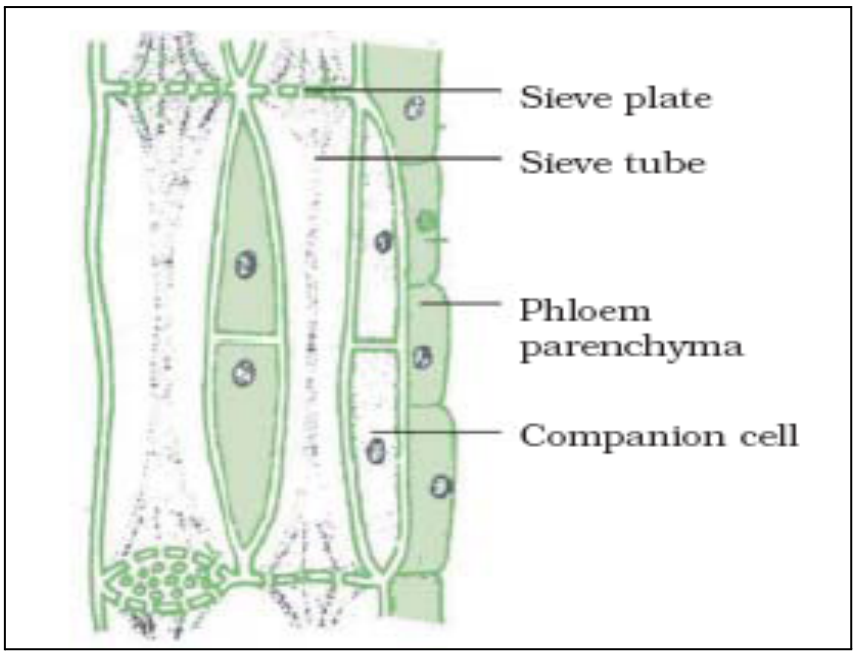

Image structure of phloem source: google images

Source: http://www.ekshiksha.org.in/eContent-Show.do?documentId=100

Phloem is a complex tissue. In angiosperms, it is made up of sieve tube elements, companion cells, phloem parenchyma and phloem fibre. Individual sieve tube elements are joined together into a sieve tube. Sieve plates, present between adjacent sieve tube elements, have pores which form an open channel between the sieve tube elements. Sieve tube elements are living cells although they lack a nucleus at maturity. Sieve tube elements are living cells although they lack a nucleus at maturity.

There is experimental proof to show that the translocation of sugars takes place in the phloem.The earliest was the girdling experiments where a ring of bark containing the phloem tissue was removed from the plant. The portion of the bark above the girdle became swollen after a week. This happened because the downward flow of sugars was impeded by the removal of the phloem tissue. This simple experiment proved that the translocation of sugars takes place in the phloem.

Image: Girdling experiment. Image: Phloem feedingaphids

Source: http://www.biology-pages.info/P/Phloem.html

Aphids have helped in the understanding of phloem translocation. Some aphids pierce their stylets into the phloem and suck the sugars through the stylet. The stylets were cut as the aphids were feeding and the stylets remained attached to the phloem even after the aphid left. The sap that oozed out of the stylet was collected and analysed. This experiment proved two points–

a) The analysis showed that the phloem exudate contain sugars
b) It proved that the phloem sap is under pressure.

Later experiments using 14C labeled carbon dioxide confirmed that translocation of sugars takes place in the phloem.

Direction of Translocation

Source – sink concept: Once it was established that translocation takes place in the phloem, questions were asked about the direction of flow - whether it is upwards or downwards, unidirectional (as in the xylem) or bidirectional. It soon became apparent that the direction of translocation is not in response to gravity and that sugars are translocated through the phloem in the upward as well the downward direction. Phloem translocation takes place from a source to a sink. A **source** is an organ that has enough sugars for its own needs, e.g., a mature actively photosynthesizing leaf. A **sink** is a non-photosynthetic organ that needs sugars for its

growth/development. However, some organs can be either a source or a sink at different stages of its development. For e.g., A young leaf is a sink in its early stage of development but becomes a source and starts exporting sugars when it is mature. A seed is a sink when it develops but is transformed to a source during germination. Similarly, storage organs like tubers, bulbs and the storage roots of beetroot are sinks in their development stage but become a sink when they sprout.

It is important to note that phloem translocation always takes place from a source to a sink. It may be in the upward or downward direction but is always unidirectional in a particular sieve tube connection. There are many source sink connections and the translocation flow may be in different directions in different source – sink connections.

Nature of Substances Translocated in the Phloem

The phloem sap contains mainly sugars, water and small amounts of amino acids, organic acids, protein, potassium, chloride and magnesium ions and some endogenous hormones. Only reducing sugars are translocated in the phloem, of which sucrose is the most common sugar.

The transport of sugars from the source to the sink cells takes place in three steps:

a. A short distance transport of the sugars from the source cells to the phloem. This is called phloem loading.

b. A long distance transport of sugars through the phloem.

c. A short distance transport of sugars from the phloem to the sink cells. This is called phloem unloading.

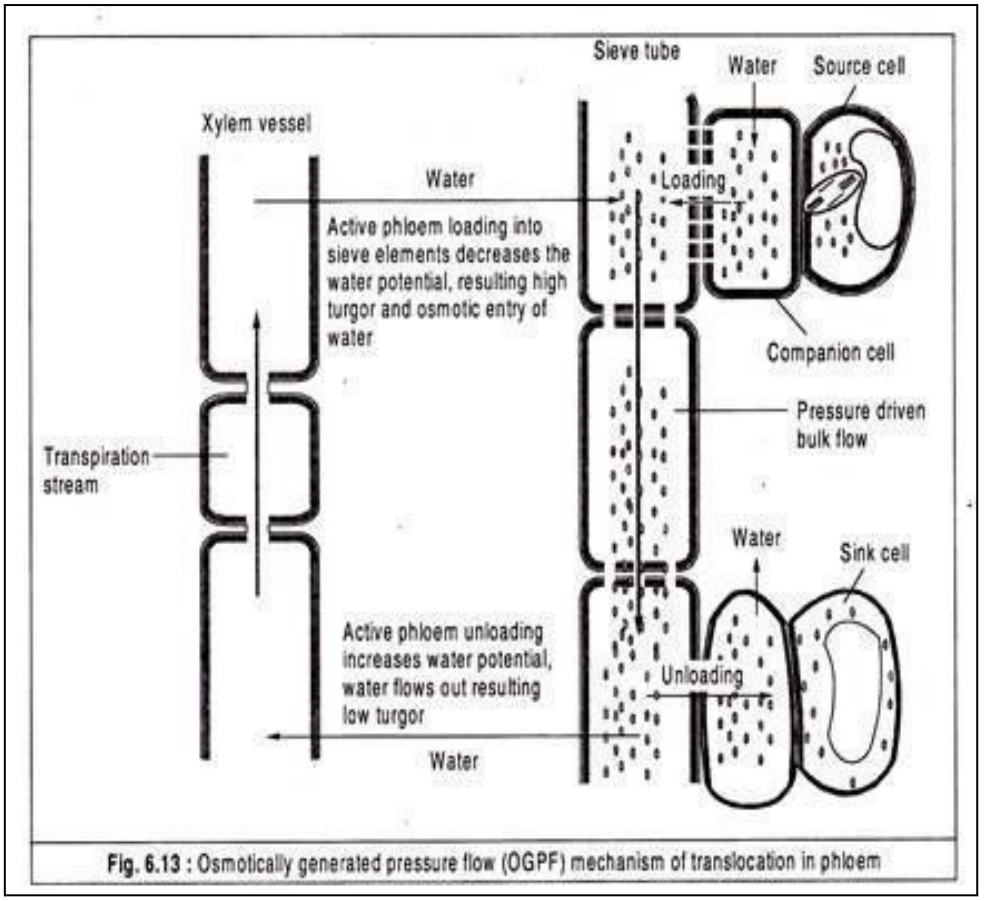

Image: Phloem translocation Image source (Google Images)

Source:

http://cdn.biologydiscussion.com/wp-content/uploads/2016/03/clip_image014_thumb21.jpg

Phloem Loading

Transport of sugars from source cells to the phloem: The sugars reach the phloem from the source cells either through the symplast (Symplastic phloem loading) or through the apoplast (apoplastic phloem which is an active process and requires energy). The sugars first enter the companion cells and are transferred to the sieve tube element through plasmodesmata connections that exist between the two.

Translocation in the Phloem by Bulk Flow

Phloem translocation is the long distance transport of sugars from the sieve elements near the source cells to the sieve elements near the sink cells. The process was first explained by the pressure flow hypothesis (also called bulk flow) given by Ernst Munch.

According to this hypothesis, an osmotically generated pressure gradient is established in the phloem from the source to the sink. Pressure gradient is established due to phloem loading at the source and unloading at the sink.

At the source, sugars are loaded in the sieve tube elements. This lowers the water potential of the sieve element and water enters the cell by osmosis. As a result, the osmotic pressure increases at the source end of the phloem. On the other hand, sugars are unloaded from the sieve tube at the sink. As a result, the water potential rises and when it becomes higher than the surrounding cells, water exits the phloem. The osmotic pressure in the phloem decreases at the sink end. A pressure gradient is thereby established in the phloem.

The phloem sap flows from the source to the sink end in response to the pressure gradient. All molecules are carried along passively with this bulk flow.

Thus phloem translocation takes place by bulk flow driven by a pressure gradient and does not require energy input.

Phloem Unloading

Transport of sugars from phloem to sink cells: phloem unloading i.e., transfer of sugars from the sieve element – companion cell complex to the sink cell could be either through the symplast or apoplast.

Concluding Remarks

In the sink tissues photo assimilates may be allocated to different metabolic pathways or partitioned between different organs. Agricultural yield is influenced by such allocation and partitioning of the photoassimilates.

Summary

Transport of photo-assimilates takes place through the phloem. Phloem translocation occurs from the source to the sink and is not influenced by gravity- it can take place in an upward or downward direction. Due to the loading of sugars, water enters the sieve element by osmosis at the source end while water is lost by exosmosis at the sink due to phloem unloading. This leads to the development of an osmotically generated pressure gradient between the source and sink end of the phloem. In response to this pressure gradient, the photo-assimilates move passively by bulk flow through the phloem.