Republic of Iraq
Ministry of Higher Education
&Scientific Research
University of Anbar
College of Science

Lecture 11

Photo assimilate Translocation

Source-Sink Relationship

Phloem loading and unloading

Experimental Evidence

Features of Phloem Cells

Mechanism of Photoassimilate Translocation

For
Dr. Enas Fahd Naji
Department of Biology

Photo assimilate Translocation

Xylem strands are responsible for transport of water and minerals from roots to the aerial parts of the plants, while translocation of photosynthetic products (photo assimilates) is facilitated by phloem elements. It is estimated that as much as 80% of the photo synthetically fixed carbon can be exported out of mature leaves. Storage or photosynthesizing organs, which have surplus sugars, can either metabolize or export them. These are known as source. On the contrary, actively metabolizing organs or the ones which store carbohydrates need to import them. These plant parts are known as sinks. A plant consists of series of sources and sinks, with many sinks competing for sugars exported by the source organs. Phloem plays a major role in connecting source and sink. In the early developmental stage of a plant, roots and shoots majorly compete for receiving photoassimilates, and later on many other organs become effective sinks. These include reproductive structures, buds and flowers, and developing grains or the underground storage organs, such as tubers. Sink strength or sink dominance refers to the capacity of sink organs to acquire sugars from the transporting vascular strands. Distribution of sugars in the sink is the key factor in determining the harvest index (HI), which refers to the ratio of dry weight of harvestable part (economically important) of the plant to the total dry weight of the plant. The higher the ratio (high value of HI), the higher the plant productivity. Thus, transport of photoassimilates is targeted as the key factor determining plant productivity. Various abiotic and biotic factors adversely affect translocation of sugars. Accumulation of sugars in the cytosol of mesophyll cells at the source is the key factor for inhibiting photosynthesis.

Source-Sink Relationship

Translocation of photoassimilates occur in phloem which can be functionally characterized into three different zones along the source-to-sink pathway. At the sources, these are often referred as collection phloem, while at the sinks, these are termed as release phloem. The connecting pathways of the two are known as transport phloem. Supply of photoassimilates from all sources does not reach all sinks. Instead, specific sinks are preferred over others by certain sources. Factors

affecting the movement of photoassimilates from source to sink are as follows:

1. Proximity of source to sink—Mature leaves (sources) located on the upper region of the aerial parts of plants usually provide photoassimilates to the developing immature leaves (sinks) on the same vertical row of leaves arranged one directly above another. Leaves present on the lower portion of stem predominantly supply underground parts of plants, whereas leaves present in the middle portion of the stem supply in both upward and downward directions.

2. Developmental stage—Root and shoot apices are usually the major sinks during vegetative growth, whereas developing fruits become the major sinks during reproductive phase. At the time of senescence, mature leaves serve as sink. Thus, there is change in the source and sink status of the growing organs during plant development.

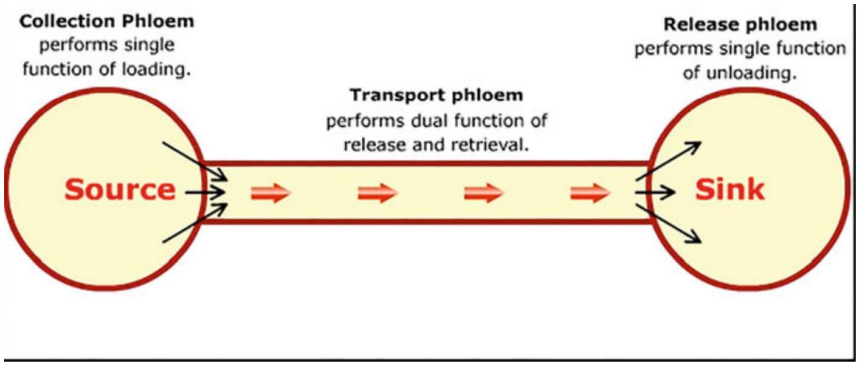
3. Vascular connections—Sinks which have direct vascular connections with source are preferred.

4. Modification in translocation pathways—Wounding interferes with the translocation pathway and leads to the alteration of translocation patterns in relation to proximity and vascular connections. In fact, vascular interconnections, known as anastomoses (reconnection of leaf veins that were previously branched out), act as alternative pathway for translocation in the absence of direct vascular connections between source and sink.

5. Sink strength—Ability of a sink to store or to metabolize sugar imports determines its capacity to compete for sugars exported by various source tissues

Removal of a sink results in increased translocation of sugars to other available and competing sinks. Young leaves act as stronger sinks in comparison to roots when supply from a source is compromised. Rapid utilization of sugars by sink cells results in lowering the concentration of photoassimilates in sieve elements of the young leaves resulting in lowering of the hydrostatic pressure. As a result, an increase in pressure gradient between source and sink is evident, and it leads to change in the

translocation of photoassimilates. This ability of young leaves to mobilize sugars toward themselves is due to their relatively high sink strength. Sink strength is dependent on the size (total weight of sink tissue) and activity of sink (rate of uptake of transport sugars per unit weight of sink tissue).



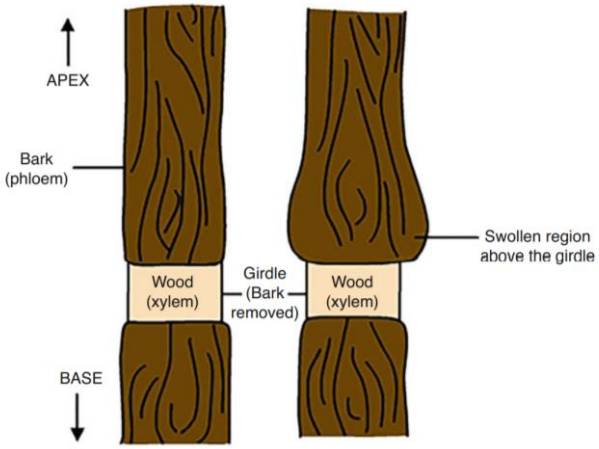
Phloem loading and unloading

Phloem loading (transfer of photosynthates from the mesophyll cells of the leaf to the phloem sieve tube elements) and phloem unloading (transfer of photosynthates from phloem sieve tube elements to the cells of a sink). During phloem loading the mesophyll cells are typically at a lower osmotic potential (higher water potential) than the sieve tube elements, thus the phloem loading requires an energy input to move sugars into an area of higher concentration. Phloem loading generates increased osmotic potential in the sieve tube elements, supplying the driving force for mass flow of assimilates. It consists of movement of sugars from symplast (mesophyll cells) into apoplast (cell walls) and then into symplast (phloem cells). When sugars move into sieve elements, the movement may be aided by adjacent companion cells . At the other end of the translocation process, phloem unloading can also limit the rate at which a sink receives assimilates. Some studies have shown that unloading is similar to loading in that the sugars move from the phloem symplast to the apoplast and then are transferred to the symplast of sink cells.

Experimental Evidence

1. Girdling

In 1686, Marcello Malpighi (an Italian anatomist) performed a classical experiment on the translocation of organic solutes. In this experiment, bark of a tree was removed in the form of a ring around the trunk. In 1727, Stephan Hales (an English clergyman) repeated the girdling experiment. In this experiment, a strip of bark around a tree trunk was removed which effectively eliminated the phloem elements. Subsequently, swelling in the region of the bark just above the girdle was observed. Contrary to this, bark region which was present immediately below the girdle shrank. The experiment demonstrated that due to girdling, transport of sugars from photosynthesizing leaves to the roots was obstructed. However, transport of water through xylem remained unaffected. The experiment demonstrated that transport of sugars from leaves to roots occurs through phloem. The plant died after some time which demonstrated that the photoassimilates are essential for growth of those plant parts which cannot perform photosynthesis.



2. Autoradiography

Availability of radioactive compounds after World War II provided scientists an opportunity to use them in various experiments. In another approach, the leaf cuticle was removed by abrasion, and then radioactive

compounds were applied directly to the leaf. Alternatively, leaf was exposed to labeled carbon dioxide ($^{14}CO2$) in a closed chamber. Subsequently, $^{14}CO2$ incorporated into the photoassimilates was analyzed which then got exported via translocation stream. The labeled ^{14}C first gets incorporated into sucrose, but later it is incorporated in many other organic compounds. Localization of these radioactive compounds can be done with the help of autoradiography technique.

3. Exudation from incision in bark

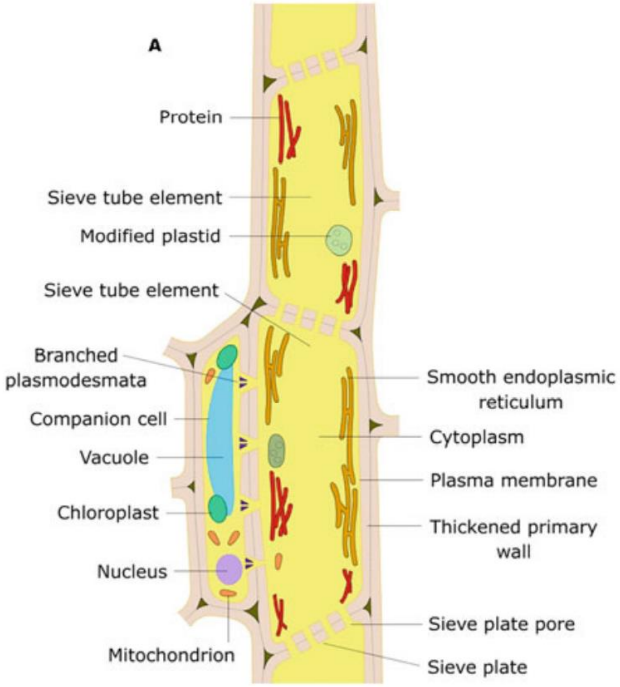
A liquid exudation containing high concentrations of sugars is observed when making an incision in the bark of a deciduous tree.

4. Analysis of sap from aphid style

High turgor pressure in the sieve-tube elements and wound reactions make the collection of the phloem sap a challenging task. Sometimes during the process of severing, phloem damage is caused, and this leads to the contamination of the phloem sap. Sudden pressure released due to damage causes disruption of cellular organelles and proteins. Dilution of the phloem sample occurs due to influx of water from the xylem. Thus, analysis of phloem sap collected after severing the phloem is usually not a preferable approach. A reliable approach for collection of phloem sap exploits aphid stylet as a "natural syringe." Aphids are small sap-sucking insects. Their mouth part consists of four tubular stylets which are inserted into shared cell wall between epidermal cells and steer them through cortical parenchyma cells and phloem parenchyma cells and finally to sieve tubes. During this navigation, aphids secrete gel saliva which hardens into tubule and facilitate the forward movement of stylet. Aphids are anesthetized with CO_2 and their stylets are cut using laser. The phloem sap oozes out from the cut end due to high turgor pressure in the sieve elements which is collected for further analysis. The amount of phloem sap collected is small. This method of phloem sap collection is technically difficult but is believed to yield relatively pure phloem sap and, therefore, gives fairly accurate details about the composition of phloem sap.

Features of Phloem Cells

Phloem consists of sieve elements (SEs), companion cells, and phloem parenchyma. In addition, phloem tissue may include fibers and sclereids also which primarily provide strength and protection. Phloem parenchyma stores and releases food molecules. Mature sieve elements (SE) are phloem cells which are specialized for translocation in long-distance transport.



Mechanism of Photoassimilate Translocation

A. Photoassimilate Loading

1. Apoplastic Loading
2. Active Symplastic Loading
3. Polymer Trapping
4. Passive Symplastic Loading

B. Photoassimilate Unloading

Phloem Unloading Occurs via Apoplast or Symplast

References:

1. Plant Physiology, 3rd ed by Lincoln Taiz and Eduardo Zeiger, 2002

2. Plant Physiology, Development and Metabolism, Satish C Bhatla , Manju A. Lal, 2018. ISBN 978-981-13-2022-4 ISBN 978-981-13-2023-1 (eBook)

3. PLANT PHYSIOLOGY Vince Ördög , 2011 .

4. Plant Solute Transport Edited by ANTHONY YEO Haywards Heath, West Sussex, UK, TIM FLOWERS School of Life Sciences University of Sussex, UK, 2007.

5. اساسيات فسيولوجيا النبات ، أ.د. حشمت سليمان احمد الدسوقي، قسم النبات، كلية العلوم ، جامعة المنصورة ، جمهورية مصر العربية ، 2008.

6. أساسيات فسيولوجيا النبات ، د. بسام طه ياسين ، قسم العلوم البيولوجية ، كلية العلوم ، جامعة قطر ، 2001.