

Lecture-13

ASSIMILATE TRANSLOCATION IN HIGHER PLANTS

13.1 TRANSLOCATION OF ASSIMILATES:

The assimilate transport is a process of exchange of metabolites among the functionally specialized organs and tissues as a coordination of activities of plants as whole.

This is essentially required to know

1. The distribution of photosynthetic products in plants
2. Their accumulation in storage organs
3. Their mobilization during resumed growth and
4. The effect of climatic factors and farming practices on the above process

13.1.1 Definition

The process of sugar movement from source to sink in sieve tube is called as translocation.

13.1.2 Types of assimilate transport

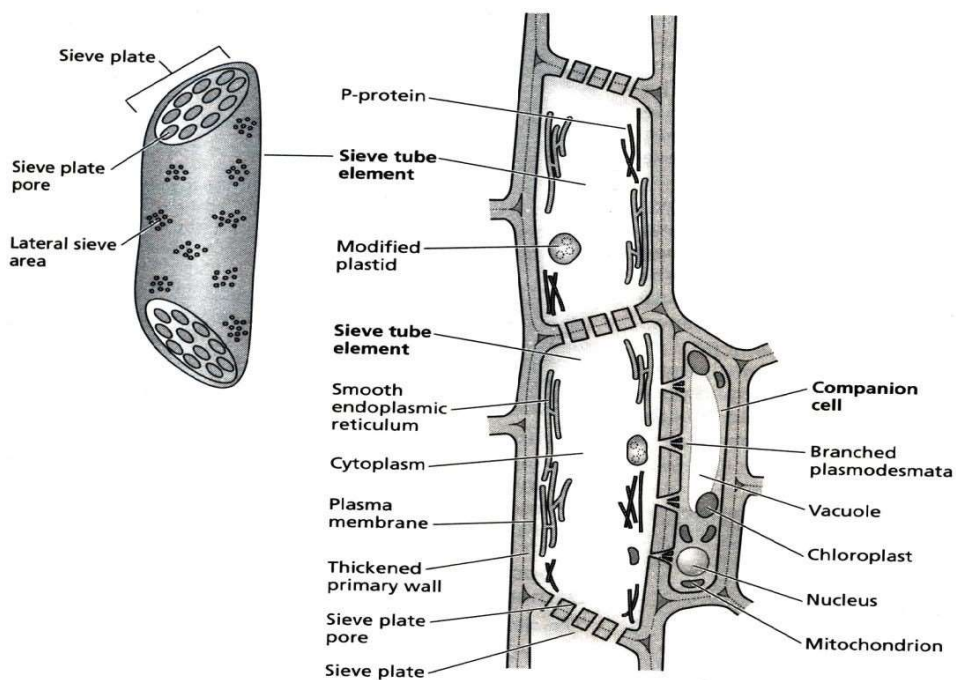
The assimilate transport is of two types depending on their distance of transport.

- A) **Short distance transport:** Movement of sugar from mesophyll cell to the vicinity of sieve elements in the smallest veins of the leaf involving a distance of only one or three cells diameter.
- B) **Long distance transport:** Translocation of sucrose and other solutes from source to sink inside the sieve elements is referred as long distance transport.

The two pathways function simultaneously and intimately inter twined forming a continuous process encompassing the entire plant. These are extending in parallel and pressed against each other resulting in the exchange of mobile substance.

13.1.3 Anatomy of phloem tissue

Phloem is a complex tissue than the xylem. The main components of phloem are sieve tubes. These are the longitudinally arranged individual cells called sieve elements with perforated end walls called sieve plates. They are living cells. The mature sieve elements appear to contain living protoplasm, although devoid of nucleus, possess differentially permeable membrane but do not have a tonoplast. Much of the protoplasm is in the form of **P-Protein** (phloem protein) a fibrillar protein.



*Figure is from reference.6

13.1.4 ASSIMILATE TRANSLOCATION IN RELATION TO “SOURCE” AND “SINK”

Assimilate partitioning involves the production of assimilates in photosynthetic organs (source) loading into sieve tubes, and translocation to the growing parts (sink), where unloading takes place. An intact plant consists of multiple “Sources” and “sink”

SOURCE

A source is any plant part that export carbon. Leaves are the principles sources of assimilates.

SINK

The centers of storage or consumption of assimilates are the “Sinks”. A sink is an organ that has a net import of assimilates which would be used for growth or storage. All actively growing or metabolizing tissues are sinks.

13.2 PATHWAYS OF ASSIMILATE TRANSLOCATION

Assimilates after they are formed in the photosynthetic cells must traverse a complex short distance of 3 to 4 parenchymatous cells (tenths of a millimeter) and get concentrated in the phloem against the concentration gradient. This involves additional energy expenditure.

In this route assimilate pass across the mesophyll cells in two pathways separated or simultaneously. They are

13.2.1. **Symplastic transport of assimilates (via plasmodesmata) (living part of the plant)**

Along this route, the mesophyll cells are interconnected with thin strands of cytoplasm penetrating the cell walls in many places called **plasmodesmata**. **Munch**

(1930) termed this continuous protoplast in an aggregation of cells in complex organisms as **symplast**.

Thus, symplastic transport can be defined as Translocation of substances from one cell to another via plasmodesmata.

13.2.2 Apoplastic transport of assimilates (via free space)

In this pathway, assimilates leave the cytoplasm across its outer membrane, on to the surface of the assimilating cells, (i.e. the apoplast) where in the solution forming a film around the free intercellular space between cells.

Thus, apoplast includes all non living cells, cell walls and intercellular spaces in stems and leaves.

13.3 ASSIMILATE TRANSLOCATION CAN BE UNDERSTOOD FROM THE FOLLOWING HEADINGS

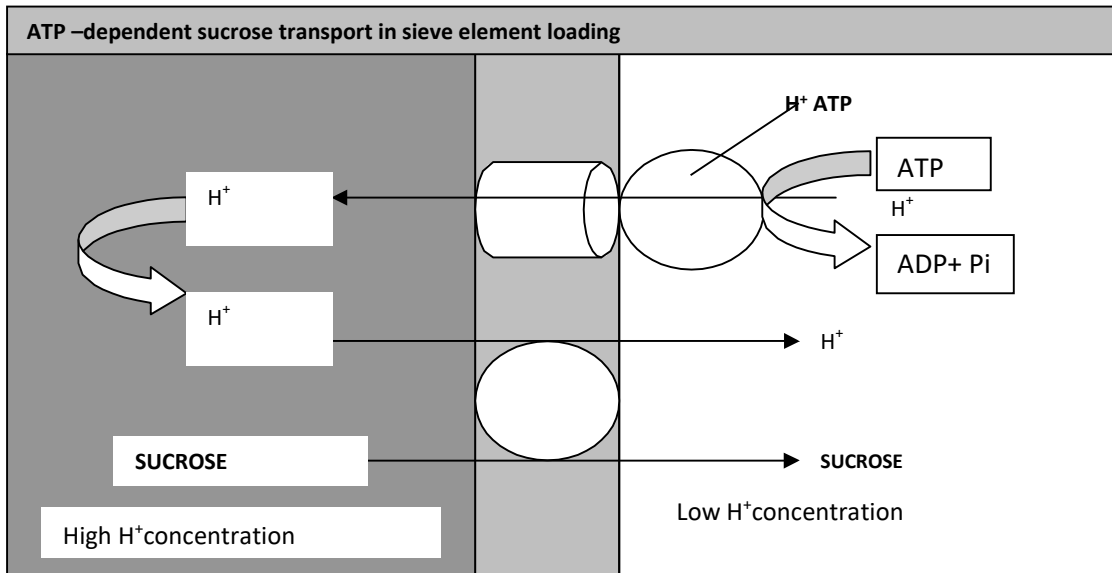
- Phloem loading
- Mechanism of phloem transport
- Phloem unloading

13.3.1 PHOLOEM LOADING

The site of phloem loading is the **sieve cell- companion cell complex** of source. In source leaves, sugars become more concentrated in the sieve elements and companion cells than in the mesophyll cells. So in phloem loading the sucrose is transported against its chemical potential gradient and is evidence for active transport of this solute.

Sugars might move entirely through the symplast via the plasmodesmata or, alternatively might enter the apoplast at some point enroute to the phloem. In the later case, the sugars could be actively loaded from the apoplast into the sieve elements and companion cells by an energy driven carrier located in the plasma membranes of these cells.

So the uphill transport of sucrose from the apoplast into the sieve cells requires energy in the term of ATP. **Giaquinta** (1977) proposed **sucrose proton transport model** involving energy. According to this an ATP ase builds up a proton gradient across the plasma membrane by splitting ATP into ADP + Pi and excreting the resulting H⁺ into the apoplast. The sucrose is taken up by sucrose proton and is transported across membrane mediated by a carrier which is activated by protonation. High ATP ase activity at the surface of the sieve element cell justified this assumption.

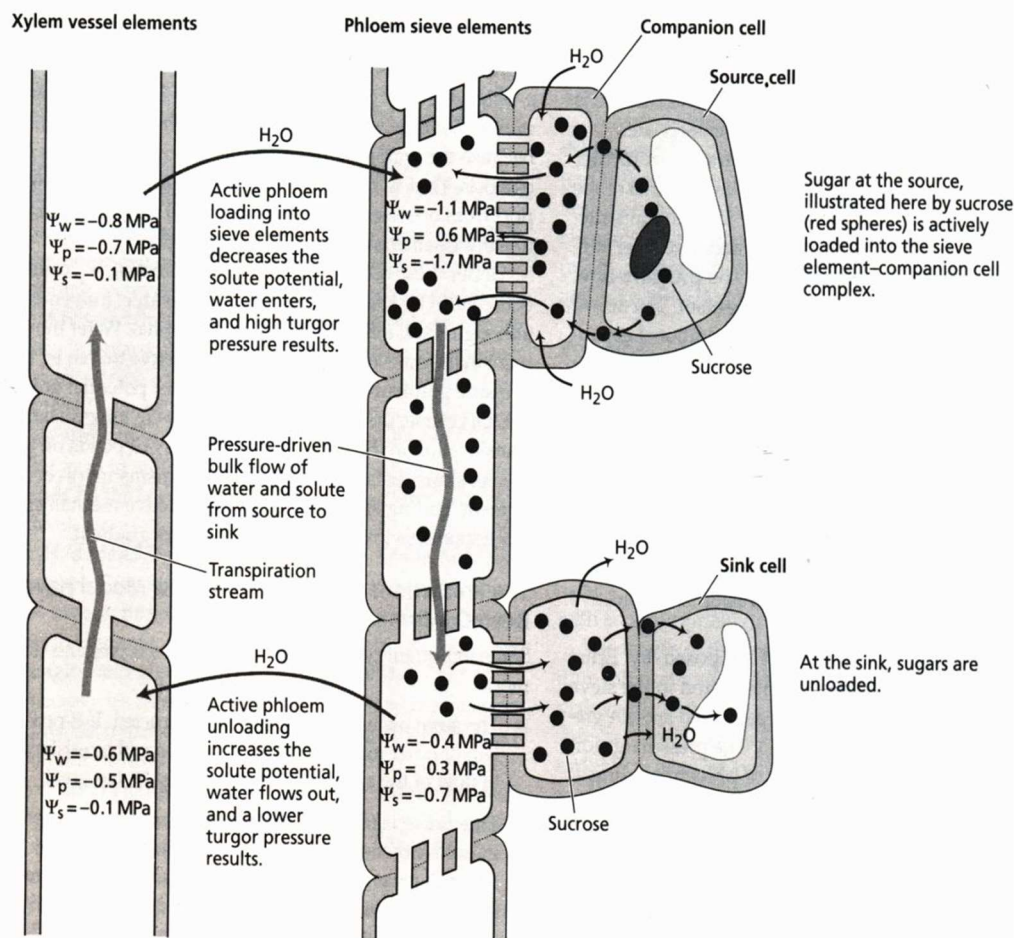


13.3.2 MECHANISM OF PHLOEM TRANSPORT (Munch pressure Flow Hypothesis)

Munch pressure flow system is the only one understandable mechanism for translocation of assimilates in plants. The workable hypothesis of Munch system is mass flow or pressure flow. It is driven by metabolic processes of sources and sink tissues. Phloem loading by the sources tissue exerts **push** and unloading by the sink tissue **pull**, both driving the mass flow in the phloem. A sequence of physiological steps occur in this system are shown in the following figure.

The assimilates from the mesophyll cells of source when actively loading up in phloem, water potential of the phloem sap decreases. Consequently water is drawn from xylem tissues into the sieve cells raising the hydrostatic pressure. This pushes assimilates to flow enmasse, from one sieve tube to the other uninterrupted through open sieve pores. About 70% of sieve plate pores are freely kept open in a number of other angiosperm species. Only on wounding **callose**, a carbohydrate is synthesized which plugs sieve pores to protect from a major loss of photosynthates.

In the physiological sink, the assimilates are removed from the sieve cells thus the water potential increased and water moves out of sieve cells into xylem. Both osmotic water up take in the sieve cells of the source and water loss from the sieve cells of sink, result in the circulation of water under pressure flow from the source to the sink (translocation) in the phloem carrying assimilates, down to the sink cell and water from sink cells to source cells (Transpiration) in the xylem.



*Figure is from reference.6

Composition of phloem sap:

Sucrose is the most important mobile organic solute (200-300 mM) followed by amino acids (30-200mM) and organic acids. Among inorganic solutes it is potassium that dominates.

13.3.3 PHLOEM UNLOADING:

The process occurs at the site of sink. In many ways the events in sink tissues are simply the reverse of the events in sources. Transport in to sink organs, such as developing roots, tubers and reproductive structures, is termed import. The following steps are involved in the import of sugars in to sink cells.

1. Sieve element unloading: This is the process by which imported sugars leave the sieve elements of sink tissues
2. Short distance transport: After sieve element unloading, the sugars are transported to cells in the sink by means of a short distance transport pathway. This pathway has also been called *post sieve element transport*.
3. Storage and metabolism: In the final step, sugars are stored or metabolized in sink cells.

This three transport steps together constitute phloem unloading, the movement of photosynthates from the sieve elements and their distribution to the sink cells that store or metabolize them.

PHLOEM UNLOADING IS BOTH SYMPLASTIC AND APOPLASTIC:

In vegetative sinks that are growing such as roots and young leaves, phloem unloading and transport into receiver cells are usually symplastic. In other sinks unloading is apoplastic.

Ex. Apoplastic unloading is required in developing seeds because there are no symplastic connections between the maternal tissues and the tissues of the embryo.

When unloading is symplastic, transport of sugars occurs through plasmodesmata to the receiver cells where it can be metabolized in the cytosol vacuole i.e., Passive unloading occurs from a high concentration sieve elements to low concentration in sink cell.

APOPLASTIC TRANSPORT IS ENERGY DEPENDENT:

When unloading is apoplastic, the transported sugars can partially be metabolized in the apoplast (free space) itself. Ex. In sugarcane sucrose splits into glucose and fructose by an enzyme invertase in the apoplast itself and glucose or fructose that is taken up by the receiver cell.

In case of apoplastic unloading, sugars must cross at least two membranes

1. Membrane of sieve element and companion complex
2. Membrane of the receiver cell.

This transport of sugars across the membrane is shown to be active Thus apoplastic transport is an energy dependent process. Phloem unloading is strictly controlled by sink metabolism. Faster the metabolism greater will be the sink demand.

It also depends upon the activity of phytohormones .In case of legumes, number of nodules and nodule activity also controls phloem unloading.
