Plant Nutrition

To perform various vital functions of the body, a living organism must be provided with sufficient energy. If we trace the origin of organic molecules in food, we will always find that they come from green plants.

We get all our organic molecules, directly or indirectly from plants.

Where to plants get their food?

Plants have roots, which absorb water and mineral salts. Water and mineral salts do not provide carbon, yet carbon-rich organic molecules such as carbohydrates are found in plants

Photosynthesis
Plants make food through photosynthesis. Photosynthesis is the process in which light energy absorbed by chlorophyll is transformed into chemical energy. The chemical energy is used to synthesize carbohydrates from water and carbon dioxide. Water and carbon dioxide are raw materials for photosynthesis. Oxygen is released during the process.

Carbon Dioxide + Water → Glucose + Oxygen

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Light Dependent Stage

- Energy from sun is absorbed by chlorophyll and converted to chemical energy.
- Light energy splits the water molecules to oxygen and hydrogen (**photolysis**)

Light Independent Stage (Calvin Cycle)

- Hydrogen used to reduce carbon dioxide to carbohydrates (glucose)
- energy required for this comes from light stage

After Photosynthesis

Glucose is either used immediately or stored.

- Glucose is used immediately by plants cells
    - Glucose is first used by the cells using tissue respiration to provide energy for cellular activities.
    - Glucose is also used for formation of **cellulose** cell walls.
- Glucose is converted into **sucrose** or into **starch** in leaves.
    - Excess glucose is converted into sucrose and transported to storage organs such as seeds, stem tubers or root tubers. Sucrose is converted into starch or other forms of storage compounds
    - During the day, rate of photosynthesis is so great that sugars are formed faster than they can be removed. Glucose in the leaf is converted into starch for temporary storage in the leaf.
    - At night, photosynthesis stops and the leaf starch is reconverted by enzymes in the leaf into glucose. Starch may also be converted into sucrose and transported away for storage.
- Glucose is used to form **amino acids** and **proteins**.
    - Glucose in leaf can react with nitrates brought to the leaf to form amino acids.
    - The amino acids are combined to form proteins, which are converted into new protoplasm within the cells.
    - Excess amino acids are carried to all parts of the plant, especially the growing regions of the plant. Here, amino acids are used to build protoplasm or stored as proteins.
- Glucose is used to form fats
    - Fats are also formed from glucose in the leaves. Some of the sugars that reach the storage organs may also be converted into fats for storage.
    - Fats may be used in cellular respiration or for forming new protoplasm, for example the cell surface membrane.

Leaf Structure and Function

External features of a leaf

Network of veins

- Carry waver and mineral salts to the cells in the lamina and carry manufactured food from these cells to other parts of the plant.
- In a simple leaf, for example Hibiscus, there is a mainvein (mid-rib) giving off branches repeatedly, forming a network of fine veins.

Lamina

- Lamina has large flat surface compared to its volume. This enables it to obtain the maximum amount of sunlight for photosynthesis.
- Large thin lamina also means that carbon dioxide can rapidly reach the inner cells of the leaf.

Leaf arrangement

- Leaves are always organized around the stem in a regular pattern. In general, leaves grow either in pairs (opposite to one another) or singly in an alternate arrangement
- This ensures leaves are not blocking one another from sunlight, and that each leaf receives optimum light.

Internal Structure of the Lamina

Upper epidermis

- Lamina has an upper epidermis made up of a single layer of closely packed cells
- Upper epidermis is covered on the outside by a waxy cuticle
- Cuticle protects the enclosed leaf tissue and prevents excessive evaporation of water. It is transparent, allowing sunlight to penetrate the leaf.
- **Does not have chloroplasts**

Mesophyll

- Mesophyll consists of two types of tissue – **palisade mesophyll** and **spongy mesophyll**
    - Palisade Mesophyll consists of one or two layers of closely packed, long and cylindrical cells. These cells contain numerous chloroplasts which enable them to absorb maximum sunlight for photosynthesis
    - Spongy Mesophyll contain irregularly shaped cells. There are numerous large **intercellular air spaces** among them to allow for rapid diffusion of gases through the leaf. Cells of spongy tissue contain fewer chloroplasts than the palisade tissue, however, they carry out photosynthesis. All the mesophyll cells are covered with a thin film of moisture so that carbon dioxide can dissolve in it.

Lower epidermis

- Beneath the mesophyll
- Like the upper epidermis, the lower epidermis consists of a single layer of closely packed cells covered by an outer layer of cuticle which reduces water loss through epidermal cells
- **Does not have chloroplasts**

Stoma

- Lower epidermis contains minute openings called stomata
- Singular : stoma
- Important in gaseous exchange

Guard Cells

Stomata generally open in the light and close in the dark.

- Has lower water potential in the day
- Concentration of potassium ions increases in the guard cells
- Chloroplasts in the guard cells photosynthesize. The light energy is converted into chemical energy used to pump potassium ions into the guard cells from neighboring epidermal cells. This lowers the water potential in the guard cells.
- Water from neighboring epidermal cells enters the guard cells by osmosis so that they swell and become turgid.
- The guard cells have a thicker cellulose wall on one side of a cell (the side around the stomata pore). Hence, the swollen guard cells become more curved and pull the stoma open.

At night:

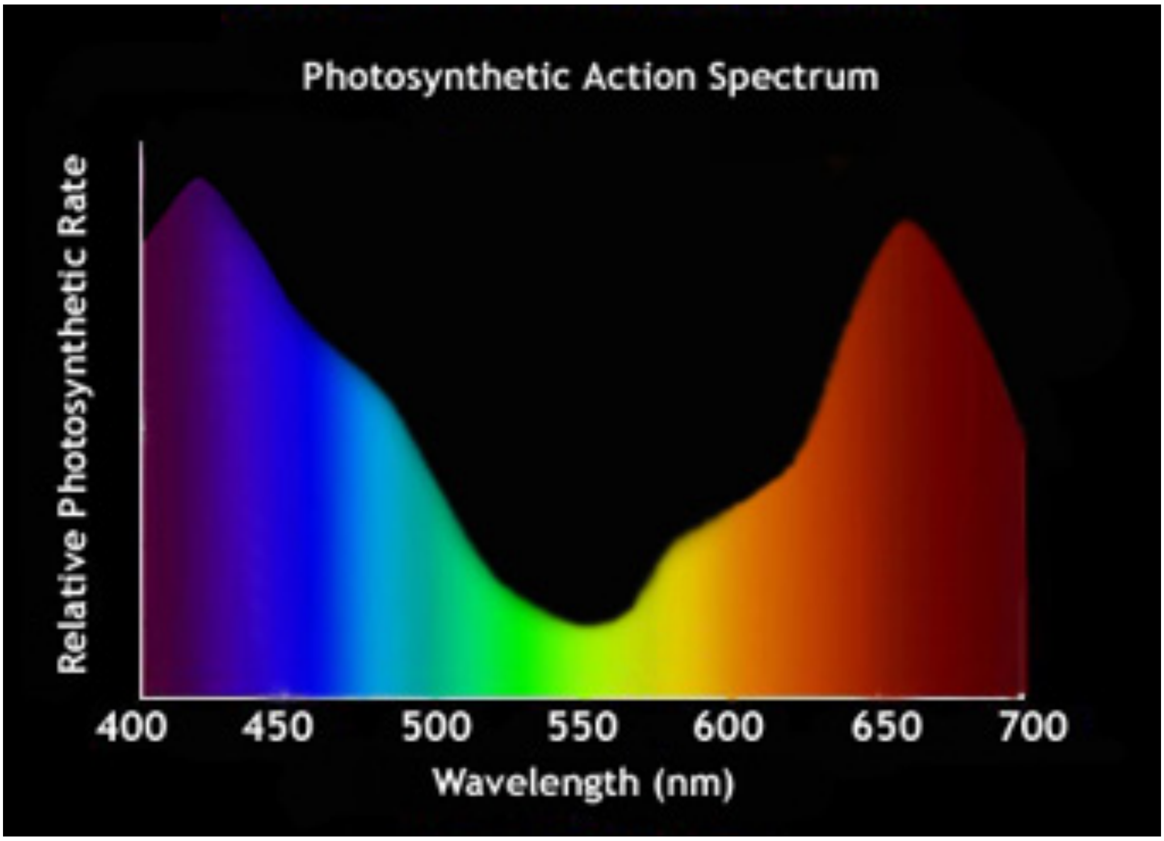
- Has higher water potential in the day
- The potassium ions accumulated in the guard cells during the day diffuse out of the guard cells.
- This increases the water potential in the guard cells and water leaves them by osmosis.
- The guard cells become flaccid and the stomatal pore closes.

In this way the guard cells can regulate the rate of diffusion into and out of the leaf, for example, the guard cells can reduce the amount of water vapour escaping from the leaf.

Stomata can close to reduce water loss even when a plant is in sunlight, for example on extremely hot days. I such situations, excess evaporation of water causes guard cells to become flaccid. The stomata pore closes. As guard cells control opening and closing of the stomata, they regulate the passage of gases such as carbon dioxide and oxygen into and out of the leaf.

Colours of light affect photosynthesis

- Certain bacteria living in water tend to cluster in areas with higher oxygen concentration.
- Oxygen-seeking bacteria will congregate near regions of algae performing the most photosynthesis, hence producing the most oxygen.



When algal cells are suspended in water on a microscopic slide, oxygen-seeking bacteria migrate toward algae exposed to blue-violet and orange-red wavelengths of light

Blue-violet and orange-red wavelengths best drive photosynthesis, while green wavelengths do so only a bit.

Limiting Factors of Photosynthesis

Factors affecting photosynthesis

- Light intensity
- The concentration of carbon dioxide
- Temperature

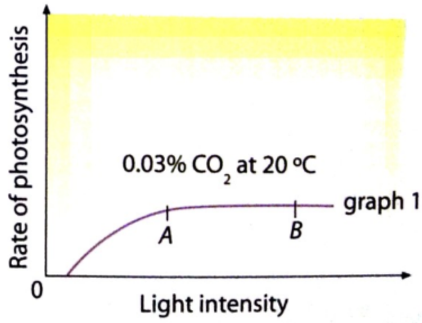


Figure 7.9 Effect of increasing light intensity on the rate of photosynthesis at 0.03% CO_2 at 20 °C

From the graph, as the light intensity increases, the rate of photosynthesis increases from 0 to A. Here, light intensity is the limiting factor. Beyond Point A, light is no longer the limiting factor since rate of photosynthesis remains constant even though light intensity increases. Some other factor, possible the **temperature** or **carbon dioxide concentration** becomes the limiting factor that causes the levelling off of the graph along AB.

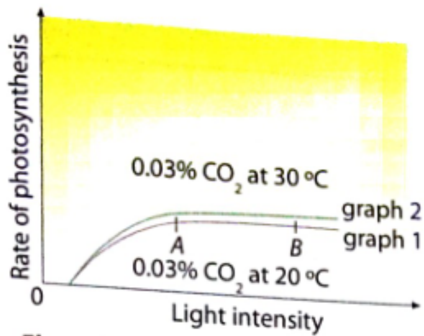


Figure 7.10 Effect of increasing temperature on the rate of photosynthesis at 0.03% CO_2

Increasing temperature from 20˚C to 30˚C while keeping the carbon dioxide concentration constant does not bring about a large increase in the rate. Temperature is not an important limiting factor in AB shown in Graph 1.

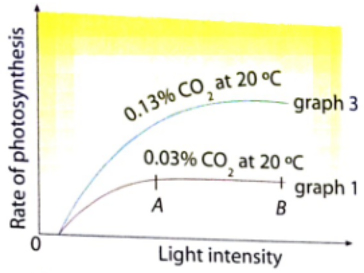


Figure 7.11 Effect of increasing carbon dioxide on the rate of photosynthesis at 20 °C

When temperature remains constant, and the carbon dioxide concentration of the environment is raised to 0.13%, the rate of photosynthesis greatly increases. This indicates that **carbon dioxide concentration** is the limiting factor in AB in graph 1.

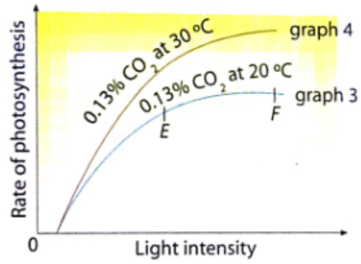


Figure 7.12 Effect of increasing temperature on the rate of photosynthesis at 0.13% CO_2

Increasing temperature from 20˚C to 30˚C, while keeping carbon dioxide concentration constant at 0.13% causes a large increase