TOMATOSPHERE™

Plants and Light: Energy input into ecosystems

Green plants are the primary source for all of the biotic energy requirements of an ecosystem.

Photosynthesis vs respiration

In green plants both **photosynthesis** and **respiration** occur. In relatively bright light photosynthesis is the dominant process (the plant produces more food than it uses during respiration). At night, or in the absence of light, photosynthesis essentially ceases, and respiration is the dominant process; the plant consumes food (for growth and other metabolic processes).

photosynthesis

$$6CO_2 + 6H_2O + \underbrace{\text{energy}}_{\text{energy in}} \longrightarrow \boxed{C_6H_{12}O_6} + 6O_2$$

aerobic respiration

$$\boxed{C_6H_{12}O_6} + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \underbrace{\text{energy}}_{\text{energy out}}$$

Photosynthesis and Respiration

The two processes are shown in the simplified equation above. Photosynthesis **absorbs** energy (from sunlight) whereas aerobic respiration **yield**s energy (as a result of the oxidation of glucose, the carbohydrate molecule shown here).

Note that these are essentially "competing" processes, one producing glucose (photosynthesis) and the other consuming glucose (respiration).

Factors Affecting the Rate of Photosynthesis

Compensation point for light

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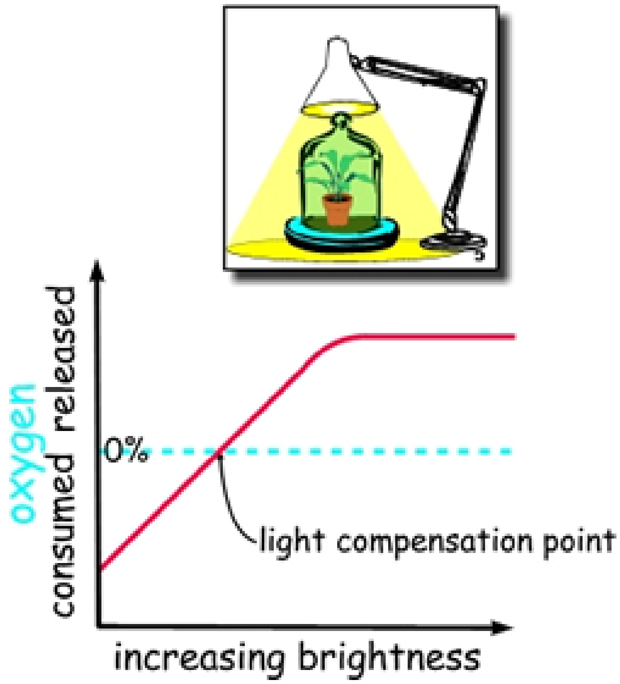


Compensation Point

One simple way to get an estimate of the level of phototsynthetic activity in a green plant is to place the plant in a sealed container and measure the rate at which oxygen is produced.

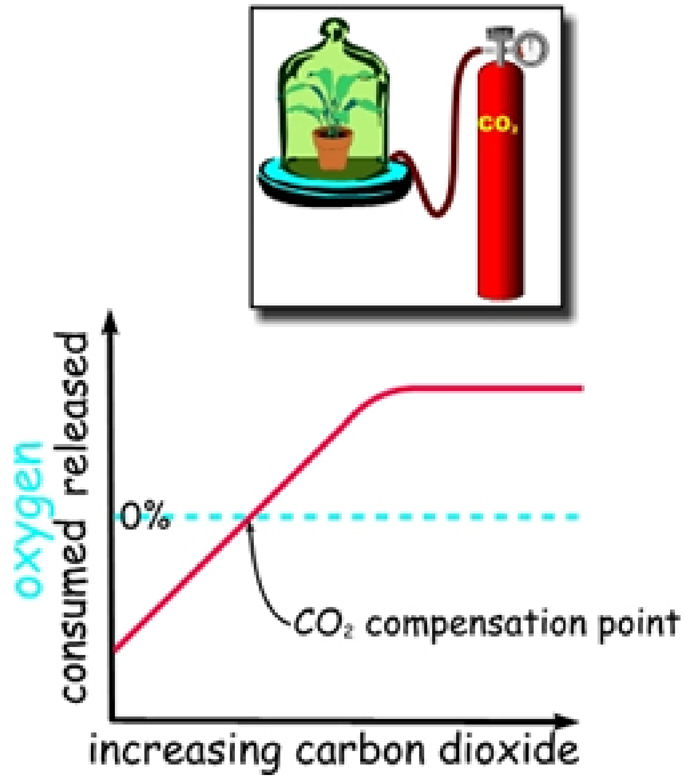
When such an experiment is actually performed it is found that increasing the brightness (intensity) of the light increases the rate of photosynthesis, but only up to a certain point, beyond which increasing the brightness of the light has little or no effect on the rate of photosynthesis.

Conversely, reducing the brightness of the light causes a decrease in photosynthetic activity.

The light intensity at which the net amount of oxygen produced is exactly zero, is called the compensation point for light. At this point the consumption of oxygen by the plant due to cellular respiration is equal to the rate at which oxygen is produced by photosynthesis.

The compensation point for light intensity varies according to the type of plant, but it is typically 40 to 60 W/m2 for sunlight. The compensation point for light can be reduced (somewhat) by increasing the amount of carbon dioxide available to the plant, allowing the plant to grow under conditions of lower illumination.

Compensation point for carbon dioxide



Compensation Point for Carbon Dioxide

Under conditions of constant and uniform illumination the rate of photosynthesis can be increased by simply increasing the amount of carbon dioxide (i.e. increasing the atmospheric partial pressure) available to plants.

One can measure the rate of photosynthesis as a function of carbon dioxide pressure by placing a green plant in a sealed container and measuring the rate at which oxygen is produced.

As the partial pressure of carbon dioxide increases there is an almost linear increase in the rate of oxygen production, which implies an identical increase in the rate of photosynthesis.

This increase eventually levels off, and further increases in the concentration of carbon dioxide have no further effect.

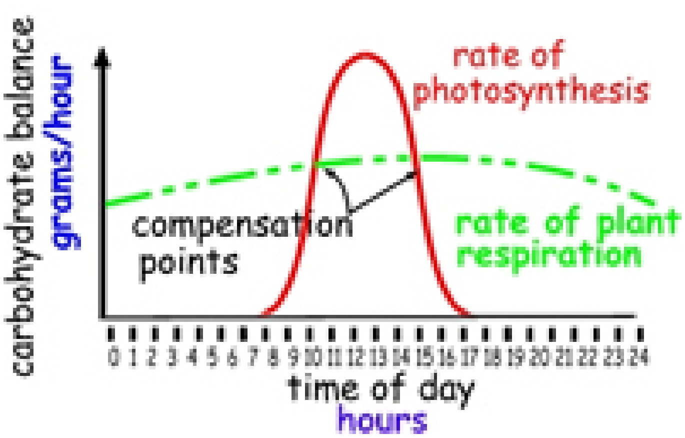
Conversely, reducing the carbon dioxide concentration reduces the rate of photosynthetic activity. The level at which the oxygen production rate drops to zero is called the compensation point for carbon dioxide.

A Day in the Life of a Plant

Compensation Point for Light (of photosynthetic plants) is the intensity of light at which the rate of carbon dioxide uptake (photosynthesis) is exactly balanced by the rate of carbon dioxide production (respiration) or equivalently, the light intensity at which the rate of oxygen production is exactly balanced by the rate of oxygen consumption.

Since it is primarily food production we are interested in, we will consider the third equivalency, the rate at which the food produced (carbohydrates) is exactly balanced by the rate at which the food is consumed.

In the figure below the red line shows the rate of carbohydrate **production** due to plant photosynthesis. The green line shows the rate of carbohydrate **consumption** due to respiration. The shape of the photosynthesis curve is due to increased **sunlight** during the day and the shape of the respiration curve is due to increased **temperature** during the day.



The Rate of Photosynthesis

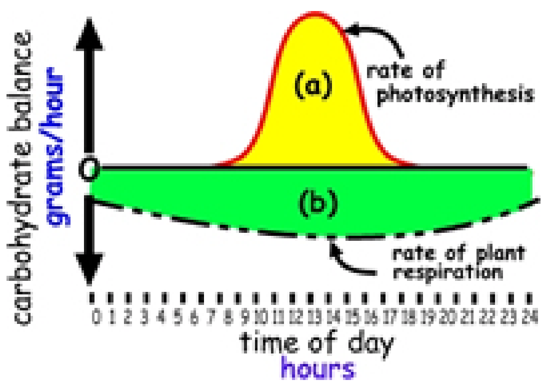
Since photosynthesis produces carbohydrates, the rate at which the amount the carbohydrates change is **positive** for photosynthesis, that is, the amount increases.

On the other hand, respiration consumes carbohydrates, hence the rate at which carbohydrates change is **negative** for respiration, that is, the amount decreases.

This is shown in the graph below.

The **area** in yellow represents the total amount of carbohydrate produced in a 24h period (due to photosynthesis). The area in green represents the total amount of carbohydrate consumed due to respiration.

For a green plant to survive, grow, and produce mature fruit, area (a) (yellow), must exceed area (b) (green).

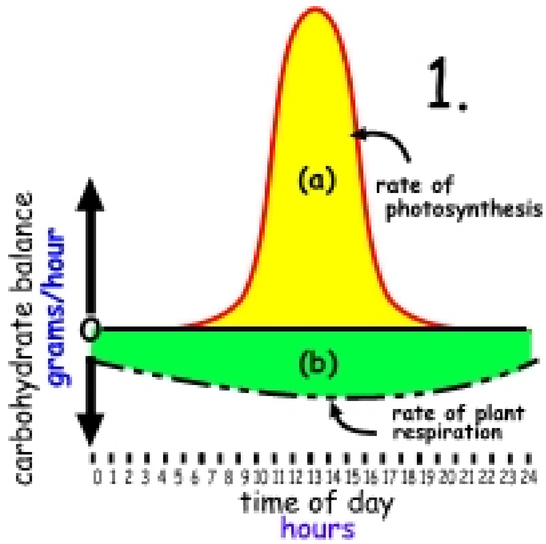


Comparing Rates of Photosynthesis and Respiration

The area (a), that is the total amount of carbohydrate production due to photosynthesis, can be increased in two ways:

1. Increase the intensity (brightness) of the light.

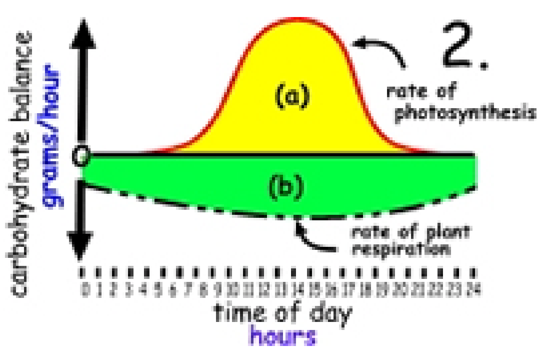
The danger is that if the light is too intense the heat it produces can damage the delicate plant cells, as well as increasing the transpiration rate, causing the leaves to wilt.
Of course, there is a limit beyond which increasing the light intensity has no significant effect on the rate of photosynthesis. This occurs for most plants at a light intensity of about 40% full daytime sunlight.



The Effect of Increasing Light Intensity

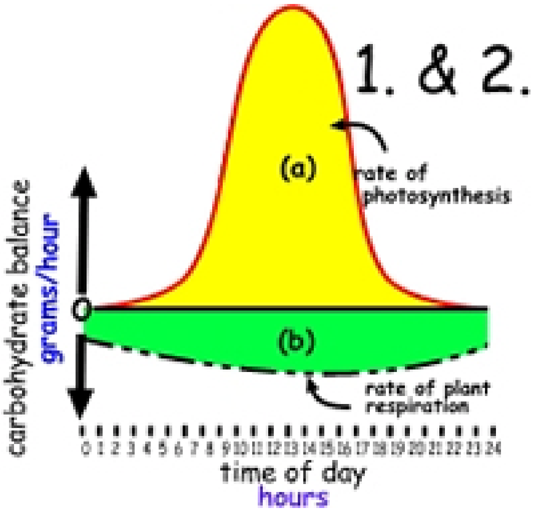
2. Increase the duration of the light that illuminates the plant leaves.

In the case of natural sunlight it is generally not possible to increase the time during which the plants receive light beyond the length of natural daylight hours.
To increase the length of time during which photosynthesis occurs requires the use of artificial lights.



The Effect of Increasing the Duration of Light

If there is enough electrical energy available both the duration and intensity of the light can be controlled to provide optimum growing conditions for green plants.
The problem is that using artificial light to grow plants is an extremely inefficient use of energy.



Increasing both the Intensity and Duration of Light

Things that we know about the relationship between plants and light

- All green plants need some light.
- Too little light is bad for green plants (below the compensation point).
- Too much light is bad for all plants.
- Increasing the carbon dioxide concentration increases the rate of photosynthesis (over a small range of carbon dioxide enhancement).

Things we would like to know about tomato plants

- What is the absolute minimum light intensity needed for tomato plants to survive?
- To what extent can the duration of light exposure compensate for low light intensity?
- How does low light exposure affect a tomato plant's ability to produce fruit?

Although the maximum intensity (brightness) of sunlight on Mars is much less than on Earth, the seasons are twice as long as on Earth. It is assumed that in the beginning all Mars habitation will occur near the Martian equator where seasonal changes are less noticeable.

A student investigation … How Much Light? – A Student Investigation … on the relationship between plant growth and the duration of available light is found in the Classroom Curriculum Documents section.