An investigation of the factors that affect photosynthesis.

Photosynthesis

$$\text{CARBON DIOXIDE + WATER} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \text{GLUCOSE + OXYGEN}$$

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}0_6 + 6O_2$$

What is Photosynthesis?

Photosynthesis is a chemical reaction occurring in the leaves of green plants. Photosynthesis is the process by which plants use the energy from light, normally sunlight to produce glucose/sugar.

Photosynthesis needs chlorophyll, carbon dioxide (from the air), water (from the soil), Sunlight energy (any light except green light.)

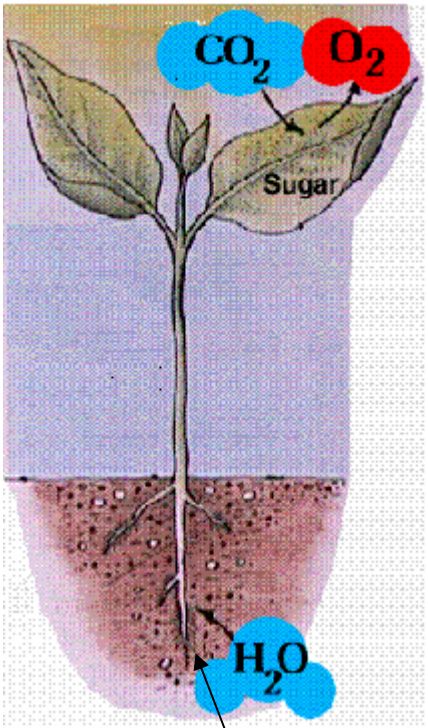


Diagram of a typical plant showing the inputs and outputs of photosynthesis

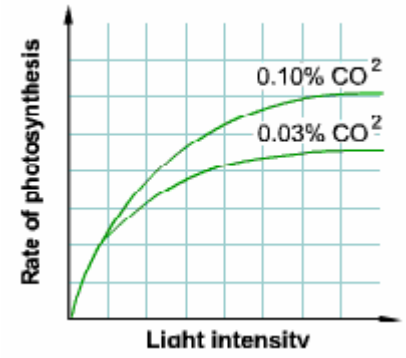
There are 3 factors that limit the rate of photosynthesis.

1. Light Intensity
2. Carbon Dioxide
3. Temperature

If any one of these factors is absent a plant CAN NOT photosynthesize.

Light Intensity.

Even if a plant has everything it requires the rate of photosynthesis will slow down if there is not enough light. Increasing the light intensity will make photosynthesis faster.



Carbon Dioxide

A plant cannot photosynthesis if there is an absence of CO_2. The concentration of CO_2 affects the rate of photosynthesis, i.e. the more CO_2 in the air the more can diffuse into the leaf.

Water

Is linked to the carbon dioxide factor because, when a plant lacks water their stomata close to prevent further water loss, at the same time, closing the stomata cells does not allow CO_2 to diffuse into the leaf.

Temperature

The rate of photosynthesis will differ if the conditions are either too hot or too cold for the enzymes to work properly.

I will investigate the affect light intensity has on the rate of photosynthesis. I plan to measure the rate of photosynthesis by counting the amount of oxygen bubbles produced in a minute when the light intensity differs.

Aim

To investigate the affect light intensity has on the rate of photosynthesis.

Prediction

I predict that the further away the lamp i.e. the lower the light intensity the slower the rate of photosynthesis i.e. the few bubbles produced. In photosynthesis sunlight provides energy, therefore the brighter the sunlight the more energy is trapped by chlorophyll in the leaves. This helps the build up process where carbon dioxide and hydrogen (in the water molecule) convert into glucose and oxygen. I also predict that light intensity will increase the rate of photosynthesis at a proportional rate where LI (light intensity) is inversely proportional to $1/d^2$. d = distance (from light source to plant.) This is true to a certain point until another factor is limiting the rate of photosynthesis (Law of Limiting Factors.)

Possible methods

There are 2 main separate methods that could be used to conduct this experiment. You could place a piece of elodea inside an inverted conical flask that is submerged in water, then on top you place an inverted measuring cylinder also full of water. After some time it is possible to record the volume of oxygen produced. However this experiment takes a very long time and is also quite complicated. After preliminary work I have decided to place a piece of elodea in a boiling tube filled with water, then place the boiling tube in a beaker of water and record the number of bubbles that are produced. From carrying out this experiment in a trial run I noticed that there are some improvements that can be noted to improve the accuracy of the results. Many bubbles were trapped on the side of the boiling tube so it is therefore necessary to clamp the boiling tube straight into the beaker. It is essential that the elodea leaves are cupped upwards. By cutting the top of the elodea and shaving a few millimeters of leaves one is able to standardise the bubbles. It is also sometimes necessary to weight the end of the elodea so it is always completely submerged by the water to do this clip a paper clip on the bottom of the elodea.

Factors to vary and to keep constant.

As we are investigating the affect of light intensity on photosynthesis it is necessary to ONLY vary the distance of the lamp i.e. the light intensity. All other factors:

- Temperature
- Type of Plant will always be elodea. Different species of plants have different photosynthetic rates due to the different leaf structures of the plants.
- Size of elodea will be kept at 7 cm as an increase of size also increases the surface area for gas exchange.
- Amount of water will always be the same in the beaker.
- Amount of Carbon dioxide is kept constant by adding a fixed amount of sodium hydrogen carbonate to the beaker and plant. The experiment should be completed in one session and under 2 hours so the plant does no use up a significant percentage of the CO_2.
- Light Wavelength (colour) is kept constant by always using the same lamp.

Will be kept constant.

Apparatus

Apparatus used:

- Large beaker
- Boiling tube
- Lamp
- Elodea
- Thermometer
- Clamp stand
- Ruler
- Stop clock
- Paper clip
- Razor blade
- Sodium hydrogen carbonate

Fair Test

To ensure the investigation is made a fair test I will make sure the constant factors are kept constant throughout the experiment. I will record the number of bubbles produced at each position 3 times in order to generate an average, and gain accurate results so accurate conclusions may be drawn. I will only start the stop clock when the first bubble has been produced i.e. so the elodea will acclimatise.

Safety

There are many safety precautions that must be obeyed whilst carrying out the experiment.

- Do not touch the electrical mains at any time
- Do not touch the light bulb
- Take extreme care when cutting the elodea with the razor blade
- Ensure all cuts are covered
- Wash hands after handling the elodea and pond water.

Method

1. Filled the beaker with 400ml of water.
2. Filled the boiling tube with 40 ml of water.

3. Clamped boiling tube over the beaker but it was covered with the water in beaker.
4. Cut a piece of elodea 7cm long with a razor blade.
5. Shaved the top of the elodea, exposing a clean cut, this standardises the bubble size.
6. Attach a paper clip to the end (that hasn't been shaved) of the elodea.
7. Place lamp 5cm away from beaker and switch on.
8. Place elodea into the boiling tube and add a small spatula of sodium hydrogen carbonate (NaHCO3.)
9. Start stopwatch as soon as the first bubble is observed.
10. Timed for 1 minute.
11. Recorded number of bubbles produced in the first minute.
12. Move lamp 5cm away.
13. Timed for another minute and recorded amount of bubbles.
14. Moved lamp a further 5cm away.
15. Carried on timing for a minute, recording bubbles and moving lamp 5cm away until the lamp was 25cm away.
16. Repeated steps 10-15 twice.
17. Recorded all results in a table (see below)
18. Plot a graph which allows you to analyse the data.

Distance of Lamp (cm)	No. bubbles of O_2 produced (per min) in exp. 1	No. bubbles of O_2 produced (per min) in exp. 2	No. bubbles of O_2 produced (per min) in exp. 3	Average No. of bubbles of O_2 produced (per min)
5	41	41	40	40.6'
10	33	31	31	31.6'
15	23	24	23	23.3'
20	16	18	18	17.3'
25	12	14	13	13

Although I dismissed the other possible method of the inverted conical flask because it took a long time I set up the experiment and recorded it over a period of 48 hours. The results also back up the results obtained from the other method. This experiment although it takes a long time is more and accurate and scientific.

Distance from lamp (cm)	Volume of O_2 given off after 24 hours (cm3)	Volume of O_2 given off after 48 hours (cm3)
5	3	7
10	2	4.2
15	1	2
20	0.3	0.7

Analysis

From the results I have obtained. I can confidently say that an increase in light intensity increases the rate of photosynthesis. The results prove my initial prediction to be correct. However my prediction that light intensity is inversely proportional to $1/d^2$ where d=distance was not completely true. The rule did exist as proven by the curved line but there was often quite a large margin of error.
Light energy is absorbed by pigments in the leaf known as chlorophyll. Chlorophyll easily absorbs blue light, in the 400-450nm range, and also easily absorbs red light in the 650-700 nm range. Chlorophyll does not absorb green or yellow light effectively but tends to reflect them, decreasing the amount of light absorbed and consequentially decreases the rate of photosynthesis. Why the rate of photosynthesis increased and decreased from the amount of light energy absorbed was investigated in the experiments.

When measuring light intensity in terms of distance the greater the distance the slower the rate of photosynthesis. When the lamp was 5cm from the elodea the average number of bubbles of oxygen produced was 40.6' and when the lamp was 25cm away form the elodea the average number of bubbles of oxygen produced was 13. While the rate of photosynthesis was decreasing, the rate at which it was decreasing at was also decelerating. This is shown in both graphs, in graph one where the line curves off at 15cm and in graph two where it curves off from the reciprocal at 1. The points at which the line curves off is due to the fact that there are other factors that limit the rate of photosynthesis. These factors do not immediately limit the rate of photosynthesis but gradually have an affect. As light intensity increases the photosynthetic rate is being limited by certain factors such as carbon dioxide and temperature. As light intensity increases further, these factors limit the rate of photosynthesis even more until photosynthesis is completely limited and the graphed line would become horizontal. This is when photosynthesis is being carried out at a constant rate, (this is known as the Law of Limiting Factors.)

Evaluation.

I feel that the experiment conducted was extremely successful since my initial predictions were supported by my results. However this photosynthesis investigation was not performed very accurately, this was mainly due to the apparatus available and some controllable and uncontrollable. A large factor in determining data accuracy is the

amount of human error during the experiments. I found that the rate of oxygen bubbles produced was sometimes so high it was hard to accurately record the number of oxygen bubbles produced. To limit this error and to improve accuracy I repeated the experiment 3 times however to improve the accuracy further one would have to take further readings. The photosynthetic rate of the elodea would eventually decrease over time so further readings may not be completely accurate.
While performing the experiment some of the oxygen produced could have either dissolved in the water or been taken up by micro-organisms in the pond weed and water. Although the amount of oxygen that could have been used is probably insignificant to my results. Some oxygen is also used during the respiration of the elodea. The second experiment that measured the volume of oxygen produced, revealed more accurate results because many bubbles in the first experiment hit the side and were therefore lost. This experiment was only carried out to back up the results because at first it was going to be too time consuming.

During the high light intensities i.e. the nearer the lamp to the elodea, I experienced counting difficulties. During the lower intensities there were also factors which affected the accuracy, for example, the elodea received some more light energy from the background as sunlight could penetrate through the blinds and from the lamps of the other students. Therefore to eliminate the background light the experiment should be conducted in a totally dark room but even then some light could reflect off the table but this would probably be insignificant. The lamp used also controlled the temperature. The lamp should have been placed behind a glass block that would hopefully decrease the affect of temperature.
The method of the experiment could probably be improved to obtain more reliable results, due to the high rate of photosynthesis readings should be taken in a shorter period of time.

Due to the convenience of this experiment it could easily be modified to investigate other factors that affect the rate of photosynthesis. Varying the amount of sodium hydrogen carbonate would vary the levels of carbon dioxide. The plant would be kept at a constant distance form the lamp and a constant amount of water would be added to the sodium hydrogen carbonate. Another experiment using almost exactly the same apparatus would be to vary the colour of the light the plant absorbs. Using translucent colour filters in

front of the lamps would vary this. I have already stated that light wave length/colour is a variable that affects the rate of photosynthesis. However there are no means to define/measure the colour of the light. Measuring the wave length is an option but the apparatus is not available. One could also investigate the temperature of water and determine what affect temperature has on the rate of photosynthesis. The lamps that we used were not the best as they projected the light rays over a large area, the distance from the lamp to the elodea was not always accurate, one way to minimise the human error would be to use lamps with dimmer switches. If this was a possible solution it would increase the accuracy of the light intensity.