Science Coursework: Photosynthesis

Introduction

For this piece of coursework I have been set a task to investigate the factors that affect the rate of photosynthesis on a green plant. I stress that it is a green plant because not all plants have the pigment chlorophyll, that's why not all plants are green. Photosynthesis is a chemical reaction occurring in the leaves of green plants. Using the energy from sunlight, it changes carbon dioxide and water into glucose and oxygen, where oxygen is the waste product. Glucose can be converted to sucrose and carried to other parts of the plant in **phloem vessels**. Glucose can also be converted into **starch** and stored. The starch can later be turned back into glucose and used in respiration.

$$\text{Carbon dioxide} + \text{Water} \xrightarrow{\text{Chlorophyll} \quad \text{Light energy}} \text{Glucose} + \text{Oxygen}$$

$$6CO_2 + 6H_20 + \text{Light energy==(chlorophyll)==>} \; C_6H_{12}O_6 + 6O_2$$

For this experiment I will be using a Canadian pondweed called Elodea. Elodea will be good for this experiment because it has a tendency to release oxygen bubble from a cut end.

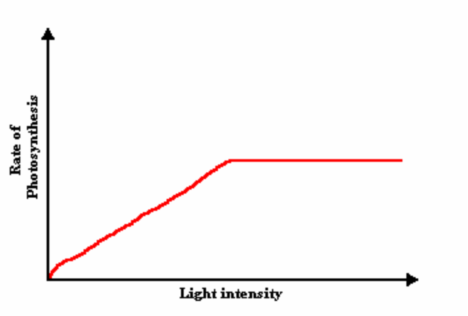
Affecting factors

As photosynthesis occurs there are many factors that can help and/or hinder the rate it occurs.

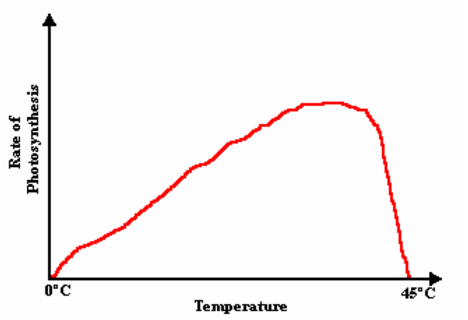
The following factors can affect the rate of photosynthesis

- Light intensity
- Temperature
- Carbon dioxide concentration
- Water concentration
- Chlorophyll concentration
- Pollution
- Mineral deficiency
- Light colour/wavelength

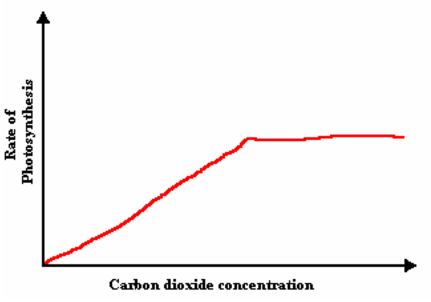
As light levels increase, photosynthesis increases until the light compensation point (LCP) occurs. The LCP is the light level where photosynthesis and respiration balance each other; where CO_2 and O_2 will move neither in nor out the leaf. Plants can survive at LCP only if stored reserves are available. With increasing light levels, photosynthesis increases and then levels off. This peak is called the light saturation point (LSP), after which there is no increase in photosynthesis with increasing light levels. Now another factor becomes the affecting factor. Energy bonds in CO_2 and H_20 are less than the bonds in O_2 and $C_6H_{12}O_6$ so extra energy needs to come from somewhere. Plants get it from sunlight. So the more sunlight there is, the more energy there is for the reaction. Light intensity isn't actually the affecting factor it is actually irradiance, which is the measurement of light that strikes the surface of the leaf.



Depending on plant species, photosynthesis can occur near 0ºC to 40ºC. However, the optimal temperature range for most plants is 20 -25ºC. Temperature affects the rate of photosynthesis because many process in photosynthesis involve enzymes therefore temperature sensitive. As the temperature approaches 45ºC the enzymes controlling photosynthesis become denatured and the rate of photosynthesis will decline to zero.



Carbon dioxide is needed during the dark reactions where it is fixed into organic compounds. The normal atmospheric concentration of CO_2 is 0.03-0.04% but increasing the concentration increases the photosynthetic rate. The short-term optimum is about 0.5% but this can cause damages over long periods, when 0.1% is better.



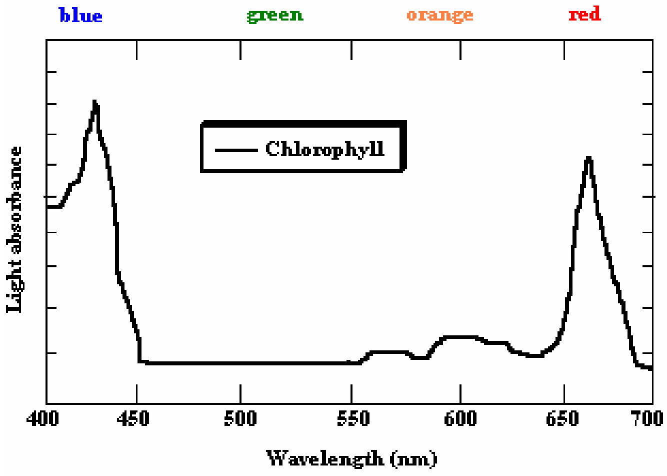
Water is a raw material for photosynthesis and essential to maintain leaf and cell turgor. Any moisture deficiencies to plants result in dehydration of cells and leaves wilting; these effects slow the rate of photosynthesis. Also when the plant is lacking water the stomata will close to reduce water loss. Therefore leading in little CO_2 being able to diffuse through. Clearly, in a water plant, like the pondweed, as long as the plant is fully submerged in water at all times, this will not be a problem.

Chlorophyll is the molecule that absorbs sunlight and uses its energy to synthesise carbohydrates from CO_2 and water. Chlorophyll concentration is not normally a limiting factor, but it can become one if chlorophyll levels are abnormally low. This can be caused by disease (such as mildew), mineral deficiency, and the normal ageing process. Iron, magnesium, nitrogen and sunlight are necessary for chlorophyll production, so lack of any one of these can lead to yellowing of the leaves. Less chlorophyll means less sunlight can be absorbed for photosynthesis.

Low levels of ozone and sulphur dioxide are very damaging to some plant leaves. Soot can block stomata (the pores on the underside of leaves that allow gas exchange), and prevent light from reaching the chloroplasts by coating the leaf.

Iron, copper and chlorine are all important minerals involved in photosynthesis. Iron is a component of the many enzymes and light energy transferring compounds involved in photosynthesis. Copper is a component of enzymes involved with photosynthesis. Plants use chlorine as chloride ion. Chloride is useful as a charge balancing ion and for turgor regulation, keeping plant cells more free of infection by disease organisms. It is essential for photosynthesis.

Photosynthesis peaks at blue light (400-450nm) and red light (650-700nm). However, light wavelengths from green to orange aren't absorbed well by chlorophyll. This is because chlorophyll reflects green light. White light is absorbed best because it contains both blue and red light.



Preliminary Experiment:

Aim

To find out what colour of light is best to use in my main experiment.

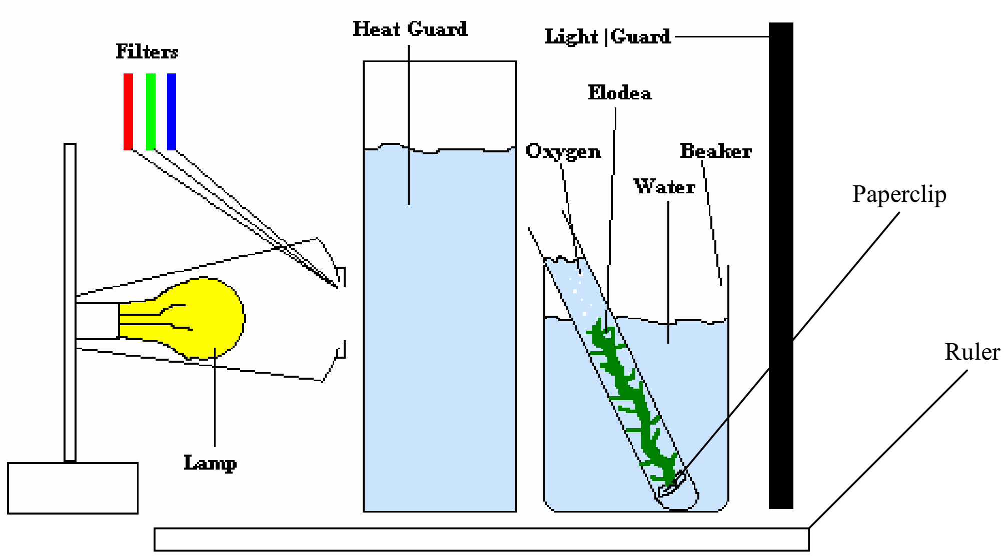
Prediction

I predict that I will find out that white light is the best colour to use. I know that blue and red lights are absorbed well by the green pigment called chlorophyll, which is the substance that absorbs the light used for photosynthesis. And as both blue and red light are in white light I predict that white light will be the best light to use in my main experiment. I don't think green will be very effective because the green light will be reflected and not absorbed because the colour of chlorophyll is green.

Apparatus

- Lamp
- Red, blue and green light filters.
- Heat guard – To make sure heat doesn't affect the experiment.
- Beaker
- Boiling tube
- Elodea
- Light Guard – To keep out as much light apart from lamp as possible.

Diagram



Plan

I plan to set up the apparatus as above with an 8cm piece of elodea. I will change the colour of the filter for each test. A paper clip will be put on end of plant to keep it fully submerged in water. The elodea will have the top of its stem cut at 45 degrees while under water. Before each test I will blow into the water in the boiling tube with a straw for 10 seconds to provide the plant with enough carbon dioxide. I will also measure the light intensity (LUX) before each test. I will count the amount of bubble that come out from the top of the stem for 3 minutes and record the result I get for each different colour filter. I will repeat each colour of light once. I have strategically placed another beaker full of water between the lamp and plant so that heat doesn't be come a factor in my experiment and is absorbed by the water in the first beaker.

Fair Test

To keep this a fair test I will have only one variable, which is the colour of light. I will need to keep all the following factors the same:

- The distance the elodea is from the light
- Temperature of the water – place a heat guard in front of lamp
- Amount of water
- Amount of Chlorophyll (I can only control this by keeping the same plant)
- Carbon dioxide concentration
- Turn other lights off and have blinds down

To make the test more reliable I will need to take the test more than once.

Filter	**Light Intensity (LUX)**			**Number of Oxygen Bubbles**		
	Result 1	**Result 2**	**Average**	**Result 1**	**Result 2**	**Average**
None	196	187	191.5	34	29	31.5
Blue	147	137	142	3	2	2.5
Green	82	85	83.5	0	1	0.5
Red	245	243	244	16	15	15.5

Conclusion

After carrying out the preliminary experiment I can see that using no filter (white light) was the best colour of light for photosynthesis. I can prove this because white light produced the most amounts of ox ygen bubbles in the three minutes. As I predicted white was the best colour and red and blue followed with green coming last. Blue didn't produce as many bubbles as expected, this could be partly due to the low light intensity compared to white and red lights. I also predicted that green wouldn't be effective and my results back up my prediction. One bubble was produced but this was most probably from another light source such as the sun.

I can now conclude that I should use white light in my main experim ent as this produced the most oxygen bubbles. I have also learnt that I should use a more effective light guard that can block out the light better. Maybe having card surround the whole experiment, obviously I cannot cover the top because this would stop me from counting the bubbles.

Main Experiment:

Input variables – light intensity is to be varied by increasing and decreasing the distance from the light source to the plant

Output variables – volume of oxygen produced (rate of photosynthesis) is to be measured by finding the volume of oxygen produced in a minute, therefore finding the rate of photosynthesis.

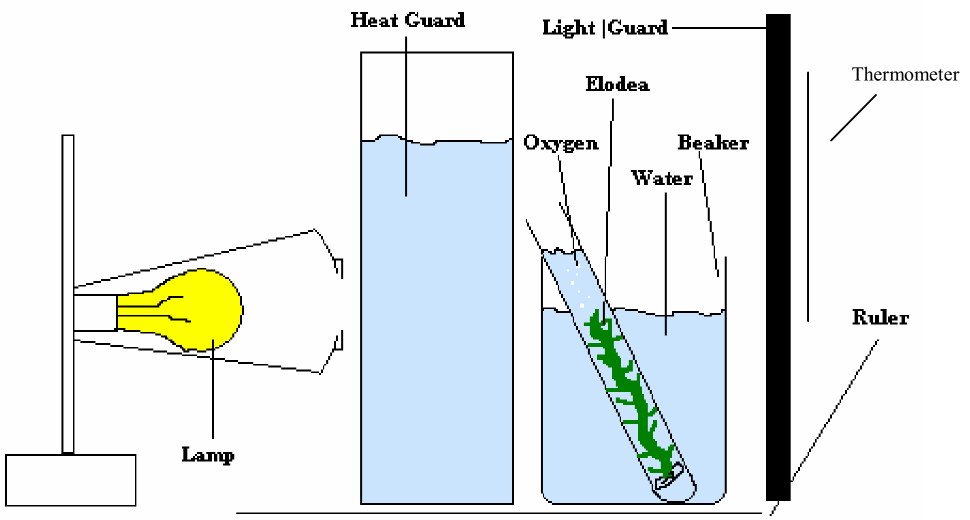
Control variables –Light wavelength (colour) – light energy is absorbed by the pigment, chlorophyll, in the leaf. Chlorophyll easily absorbs blue light, in the 400-450 nm range, and also easily absorbs red light, in the 650 -700 nm range. However it does not easily absorb green or yellow light, rather it reflects them, decreasing the amount of light absorbed, and therefore the rate of photosynthesis. This can easily be controlled, simply by using the same lamp throughout the experiment.

Carbon dioxide concentration – This can affect the rate of photosynthesis, since if there is too little CO_2, it can become the limiting factor. In this case, as long as the experiment is done over a short period of time, the amount of carbon dioxide used up by the plant will not be sufficient enough to cause the carbon dioxide concentration to become the limiting factor, but just in case it does affect my experiment I will blow into the water with straw to provide the plant with enough CO_2. If my experiment were to be performed over a longer period of time, for instance 24 hours, I would add a fixed amount of Sodium hydrogen carbonate to the water, ensuring a large enough supply of carbon dioxide.

Water availability – water is also required in the photosynthesis reaction, and when it is lacking, the plants' stomata close to prevent further water loss. The closing of the stomata cells also leads to little carbon dioxide being able to diffuse through. Clearly, in a water plant, like the pondweed, as long as the plant is fully submerged in water at all times, this will not be a problem.

Temperature – Enzymes are used in the photosynthesis reactions of a plant. Therefore, temperature can increase the rate of photosynthesis, until a point at which the enzymes denature. The plant would photosynthesise best at just above room temperature but any inaccuracy could damage my results, I am therefore going to perform the experiment at room temperature, checking the temperature frequently, in case the heat given off from the light should slightly raise the temperature, in which case I shall simply let the water cool down again.

Diagram



Apparatus

- Lamp
- Heat guard (beaker filled with water)
- Boiling tube
- Beaker
- Elodea
- Ruler
- Paperclip
- Light guard
- Stopwatch
- Thermometer
- Straw
- Cold water

Method

1. Set up the apparatus as above but leaving out the pondweed.
2. Fill up the heat guard, beaker, boiling tube full of tap water.
3. Take one piece of elodea and cut to 8cm in length.
4. Pull 1-2cm of leaves off the top of the plant leaving a clear stem.
5. On the other end hook a paperclip around to hold the pondweed down when in the water.
6. Take the pondweed and submerge it in the water in the boiling tube.
7. Once in the water cut the tip of leafless end at an angle making sure it is under water at all times.
8. Put the plant at the set distance from light.
9. Set up the light guard around the whole experiment.
10. Leave the plant to acclimatize to its conditions for 2 minutes.
11. Take light intensity reading.
12. Once acclimatized blow into water with a straw for 10 seconds.
13. Now count the bubble for 10 minutes while recording the amount of bubbles produced every minute.
14. Repeat steps 8 to 12 for every distance twice.

I set up two plants at the beginning of the experiment to see which one would photosynthesise better; I did this to make sure I will have a plant photosynthesising properly.

Prediction

I predict that if the intensity of light increases, so will the rate of photosynthesis. Furthermore, I hypothesise that if the light intensity increases, the rate of photosynthesis will increase at a proportional rate until a certain level is reached, and the rate of increase will then slow down. Eventually , a level will be reached where an increase in light intensity will have no further effect on the rate of photosynthesis, as there will be another limiting factor, in this case probably temperature. I also predict that if I double the distance between the lamp the plant the light intensity will half. Because of this I will predict further that half the light intensity will half the rate of photosynthesis. This will happen because the light intensity and the distance between the lamp and the plant will both affect the irradiance level, which is the amount of light that strikes the leaf. Obviously if you move the plant further away from the light source less light will be able to reach the plant.

Fair Test

To keep my experiment as fair as possible I will only have 1 variable and that is light intensity.

I will keep the following factors the same:

- Light wavelength (colour) – light energy is absorbed by the pigment, chlorophyll, in the leaf. Chlorophyll easily absorbs blue light, in the 400 -450 nm range, and also easily absorbs red light, in the 650-700 nm range. However it does not easily absorb green or yellow light, rather it reflects them, decreasing the amount of light absorbed, and therefore the rate of photosynthesis. This can easily be controlled, simpl y by using the same lamp throughout the experiment.
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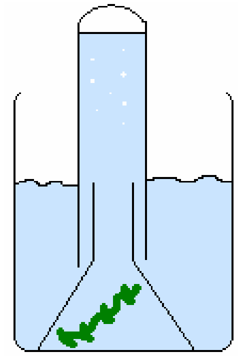
If I fail to keep all other factors the same this could change the results and this would not be a fair test. For example if I did change the light wavelength for one of the tests this would change the results considerably.

Accuracy

Part of having a successful experiment is keeping the test as accurate as possible. I will do this by repeating my experiment again. By repeating my experiment I can find an average this will make my results more reliable in case any anomalies occur. I will measure the distance between the lamp and the plant accurately and make sure I read figures of the stopwatch and thermometer carefully. I will specifically use a stopwatch and not a clock because they are more accurate and the reading can be taken easily.

The most accurate method to carry out my experiment would be to set up the apparatus as below.



By setting up the experiment like this the amount of water displaced by the oxygen bubble can be measured. But the problem with this is that it would take over 2 days and it would be impossible to control all factors. This would be unfair, as my school doesn't have the necessary equipment. If I could monitor all factors for 2 days this would be the best way to carry out the investigation.

Safety

To keep my experiment as safe as possible I have tried very hard to keep any electrical equipment away from the water and I have followed standard lab rules, and consulted them, but found no serious safety issues that needed to be planned around for the experiment.

Analysis

From these results, I am able to say that an increase in light intensity does certainly increase the rate of photosynthesis. As the distance between the light and the elodea increased the rate of photosynthesis decreased.

The gradual decrease in the rate of increase of the rate of photosynthesis shown on graph 1 (the shallowing of the curve) can be attributed to the other factors limiting the rate of photosynthesis. As light intensity increases, the photosynthetic rate is being limited by certain factors, such as carbon dioxide and temperature. These factors do not immediately limit the rate of photosynthesis, but rather gradually. As light intensity increases further, so the rate of photosynthesis is being limited by other factors more and more.

From the results table it can be seen that when the distance from between the light and the elodea is doubled from 10cm to 20cm the amount of bubble produced is also nearly double. Obviously it will not be perfectly double but most of the time it is within 20 bubbles difference. Also when the distance is doubled from 10cm to 20cm the light intensity also doubles. This shows that the light intensity and the rate of photosynthesis are clearly related.

Overall, my graphs and my results support my predictions fully. My idea that the rate of photosynthesis would increase with light intensity was backed up by my results. This is because a higher light intensity involves a greater level of light energy, which can then be transferred to a special protein environment designed to convert the energy. Here, the energy of a photon is used to transfer electrons from one chlorophyll pigment to the next. When enough energy has been gathered at a reaction centre, ATP can be synthesised from ADP. The oxygen collected in the experiment is the waste product of this reaction, and so it is clear to see that the more light energy, the more ADP is being converted into ATP and more oxygen is produced as a result.

Evaluation

Overall, I would state the experiment as a success since my predictions were supported by my results. This photosynthesis investigation was probably not performed as accurately as it could have been due to some controllable and uncontrollable conditions. Some mistakes can be corrected.

While performing the experiment, the piece of elodea did not photosynthesise at a steady rate, even when the distance from the plant to the light source was kept at a constant. The second set of readings at 0 cm was far greater than the first set of readings at 0 cm. The plant not being acclimatised to the conditions on the first reading could have caused this.

The negative effects from this problem may be inaccurate data for some readings. These would show up on my graph. However, there seemed to be few anomalies than was expected when the experiment was being performed. Almost all readings were in correlation with each other and all of the anomalies were in the high photosynthetic rate end of the results. This was when the distance from plant to light source was only 0 cm.

Accuracy of data is largely due to the amount of human error during experiments. The rate at which oxygen bubbles were being produced by my plant was so high that I found it difficult to count the amount of bubbles. I estimate a margin of error of at least 5 bubbles for each reading taken. To improve the accuracy of the results, the readings would have to be taken several more times. The photosynthetic rate of the same piece of pondweed would eventually decrease over time anyway. More repetitions would, however, improve the overall reliability of the results.

While performing the experiment, some of the oxygen produced from photosynthesis may have dissolved into the water. Microorganisms living on the pondweed may have even used some oxygen. The amount of oxygen dissolved or used by microbes is probably insignificant to my results since the accuracy at which I measured was not high enough. Some oxygen is also used during the respiration of the plant. But since only bubbles were counted, the volume of bubbles was not as important. But the volume of oxygen produced is important, since it was volume in terms of bubbles that were measured. As the rate of photosynthesis decreased due to a decrease in light intensity, the size of the bubbles produced also became smaller. This change in bubble size was no accounted for when the results were analysed. For a more accurate analysis of the collected data, volume should have been measured instead of bubble quantity since the size of bubbles can vary. Using a capillary tube in place of the test tube so that the volume of each bubble could have been measured could have done this. Or if I had the right equipment I could fit a device that measured the increase of pressure in the boiling tube.

During the high intensities I had experienced counting difficulties of the bubbles being produced. There are also factors affecting accuracy at low light intensities. With low light intensity, the elodea receives some light energy from background light such as sunlight seeping through blinds or the light from the lamp of another student's experiment. To eliminate all background light, the experiment must be performed in a completely dark room.

The method of the experiment could probably also be improved to obtain more reliable results. As already mentioned, the a capillary tube should be used in place of a test tube to accurately measure the volume of the oxygen produced. Due to the high rates of photosynthesis of the pondweed, readings should be taken within shorter time periods. I had originally chosen to count the number of bubbles in one minute but this produced miscounts in the readings. If during a repeated experiment, counting bubbles is still used, there is a smaller chance for human error when counting within a smaller time frame.

To take my experiment further I could instead of making the distance the variable, I could make the light intensity the variable. Because when carrying out the experiment it wasn't exactly double the light intensity when you double the distance. So to get around this problem the plant could be moved away from the light until it is a certain light intensity. So for every reading I will set the light intensity to go up 50 lux every test done. I will do this buy increasing the distance between the plant and the lamp until it reaches the correct lux. This would make sure that the effecting factor was light intensity and not the distance. Even though the distance does affect light intensity and light intensity is supposed to be proportional to the distance this wasn't accurate enough to produce accurate results. This could lead to the question of whether or not other types of light, such as fluorescent lights or halogen lights, would have a different effect on the rate of photosynthesis. The only problem of this experiment is that in my school we don't have very accurate equipment and the light intensity fluctuates anywhere between 10-20 lux on the machine.