GCSE Biology - Photosynthesis Coursework

Aim

The aim of my experiment was to determine whether or not the intensity of light would affect the rate of photosynthesis in a plant. To do this, I placed a piece of Canadian pondweed in varying light intensities, and observed the amount of oxygen being given off. I used Canadian pondweed because of its unusual quality of giving off bubbles of gas from a cut end, when placed in water.

Introduction

Predictions

I predicted that as the intensity of light increased, so would the rate of photosynthesis. Furthermore, I hypothesised 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 go 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.

Preliminary work

Initially, to ascertain a suitable range of distances at which to record results for my experiment, I did a preliminary investigation in which I recorded the number of bubbles of oxygen given off in a given time at various light intensities. To alter the light intensity, I placed a lamp at various distances from the plant. I also therefore needed a way of accurately measuring the light intensity, and I did this using a photometer. I recorded the lux reading (unit of light intensity) at each distance. I got the following results:

Results of preliminary experiment

Distance (cms)	Light intensity (lux)	No. Bubbles
45	55	12
40	80	12
35	110	13
30	149	14
25	208	16
20	310	18
15	590	20
10	945	21
5	1015	21

Although this is a very quick, simple and efficient way of obtaining an idea of the trends for the graph, and the boundaries for the measurements, this experiment was not in itself in my opinion accurate enough to be the basis of my main experiment. This lack of accuracy was mainly due to the fact that by simply counting the bubbles, I was relying on each bubble being exactly the same size, which they clearly were not. The preliminary experiment will, however, give me a best fit curve to which I can compare my main graph, and also points at either end of my results at which it is clear to see light intensity has little or no effect. Here, it was in fact at a light intensity of around 950 when it seems that another factor such as temperature or carbon dioxide concentration has become a limiting factor. In my main experiment therefore, it will not be necessary to take readings above this point. It also shows that while my outer limits are justified, it would be better to take more readings between the distances of 10 and 20 centimetres, as the distance between the points is large at this point, and so I have decided to take readings at the following distances: 5, 10, 12, 14, 16, 18, 20, 25, 30, 35, 40 and 45, cm's.

Method

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, and thus 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, thus impeding the viability of the experiment. 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. 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, thus 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. This 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 will increase the rate of photosynthesis, until a point at which the enzymes denature. Although performing the experiment at a temperature slightly higher than room temperature, perhaps 25°C, would have a positive effect on the accuracy of the readings I took, as it would reduce the percentage error, by increasing the volumes, I decided that the inaccuracy of maintaining a constant temperature would outweigh any advantages. 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 refill the beaker with more water after each experiment.

Method

Apparatus list

Desk lamp

Audus apparatus
Canadian pond weed
Knife
Clamp
Pond water
Thermometer
Test-tube
Beaker
Cold water
Stopwatch

Cut a stem of Canadian pondweed of about 3cm in length. Fill a test-tube with pond water, and place it in a clamp, and then in a large beaker of cold water. Connect the end of the pondweed to the Audus apparatus. Insert a thermometer into the beaker, and record the temperature at the beginning and end of each experiment, merely as a precaution against a significant rise in temperature, which is not expected. Set up a lamp at a set distance from the plant, ensuring that this distance is from the filament of the lamp to the actual

pondweed, rather than the edge of the beaker. The light intensity was measured in the same way as described in the preliminary experiment, and assumed to be the same at any point at any particular distance. When bubbles are being produced at a steady rate, clear any previous bubbles from the tubing by moving the syringe. Start the stopwatch, and wait for 1 minute. Move the bubbles, which have been collected at the bend in the tubing to the part of the tube with a scale. Find the length of the bubble collected. Repeat for all other readings, and then repeat all readings a second time to get an average result for each distance.

Audus apparatus

Using the described method, I found the following results:

Results for main experiment

Distance (cm)	Light intensity (lux)	length 1 (mm)	length 2 (mm)	average length (mm)
5	1015	3.5	3.5	3.5
10	945	3.5	3.5	3.5
12	770	4	3	3.5
14	639	3.5	3.5	3.5
16	500	3	3.5	3.25
18	395	3	3	3
20	310	2	3.5	2.75
25	208	1.5	2.5	1.75
30	149	1.5	1.5	1.5
35	110	1	1	1
40	80	0.5	1	0.75
45	55	0	0.5	0.25

Although, because I was using light intensity as my variable, I did not need to record the distances as well, I did, simply to use them as a marker for each result, so that I only had to record the light intensity once at the beginning and from then I just had to align the lamp at the correct distance each time.

Analysis

My graph was in the form of a best-fit curve. I drew it as a curve rather than a straight line because of the clear pattern of the points. This meant that the rate of photosynthesis increased as the light intensity increased. This was because photosynthesis is a reaction, which needs energy from light to work, so as the amount of energy available from light increased with the rise in light intensity, so did the amount of oxygen produced as a product of photosynthesis.
My graphs showed that the relationship between the light intensity and the rate of photosynthesis was non-linear, as both graphs produced a best-fit curve. However, as I expected in my hypothesis, it does appear that for the very first part of the graph, the increase in rate is in fact proportional to the increase in light intensity (i.e. a straight line) and I can show this by taking some readings from the graph:

	Light intensity	Rate of photosynthesis
(All increase by the same factor)	100	1 (mm/min)
	150	1.5 (mm/min)
	200	2 (mm/min)

From these results, I am able to say that an increase in light intensity does certainly increase the rate of photosynthesis. The gradual decrease in the rate of increase of the rate of photosynthesis (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, until the rate of photosynthesis is constant, and so is almost certainly limited in full by another factor.

Overall, both graphs and my results support my predictions fully. My idea that the rate of photosynthesis would increase with light intensity was comprehensively 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 in fact the by-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

Although I feel that my experiment was sound overall, I thought there were many points at which the accuracy was not perfect. As I have already stated, my preliminary experiment was not accurate enough to justify being used as my main experiment, mostly due to the fact that I was relying on all the bubbles being the same size, which they clearly weren't, however many of the smaller inaccuracies also apply to my main experiment.

Firstly, the distance between the light sources and the Canadian Pondweed were not measured to a very high degree of accuracy, especially when you note the fact that the distance should have been measured exactly from the filament of the light bulb to the centre of the plant, and it is possible here to find a percentage error. I estimate that the error could have been up to 0.5cm and I will find the percentage error for the largest and smallest reading using this estimate:

Percentage error = possible inaccuracy

total reading

% error	distance
10	5cm
1	50cm

It is clear to see that the percentage error is much less for the larger distances. Although I was not actually using the distances as part of my results, I used them as a marker for where the lamp was placed each time, as I assumed that the light intensity would be the same each time at a particular distance. Therefore, any inaccuracies in measuring the distances, i.e. if a distance was slightly different when doing the actual experiment from the distance at which I earlier measured the light intensity, an error would ensue.

The second major inaccuracy was in measuring the volume of oxygen given off.
When reading the syringe there could have been an error of 0.25mm, and again it is possible to find a percentage error.

% error	volume
3.57	7ml
50	0.5ml

For the smallest volumes this is clearly a massive error, and to improve this, it would be necessary to do the readings over a longer period of time, therefore increasing the volumes, and in turn reducing the percentage errors.
Another error would have been due to background light in the vicinity. We tried to reduce this error by closing all blinds in the laboratory, but due to practical reasons, we could not all perform the experiment in a separate room, and we therefore experienced light pollution from other student's experiments. This would have had a very marginal effect on my results as a whole, but to eliminate this problem completely, it would have been necessary to perform the experiment in a totally dark room.
A further inaccuracy was in the heat generated by the lamp. As I have earlier described, temperature has a very noticeable effect on the rate of

photosynthesis, and so any increase in the temperature of the pond water would have had serious effects on the accuracy of my results. To ensure this did not happen, I monitored the temperature of the water before and after every reading, to check that the temperature did in fact not rise. It turned out not to be a problem, as over the short period of time taken by my experimental readings, the temperature did not rise at all. However, if I were to extend the time of my experiment to 5 minutes for each reading for example, which would have the effect of reducing other percentage errors, I would have to find some way of keeping the temperature constant. One way of doing this would be to place a perspex block between the lamp and the plant, which would absorb most of the heat, while allowing the light energy to pass through.

As I mentioned in my planning, carbon dioxide concentration could have been an error in the experiment, however, I feel that due to the short period of time taken, there is very little chance that the concentration would ever have been so low as to have become the limiting factor. Again if I were to carry out the experiment over a longer time period, it would have been necessary to add sodium hydrogen carbonate to the water to increase the carbon dioxide concentrations.

The last inaccuracy, though a small one, was in the time keeping. The main problem here was in when to begin the minute. If for one reading, the minute was started just after one bubble had been produced, and in another reading it was just before, this could have had a negative effect on the accuracy of my results. I therefore ensured that in each case I started the stopwatch just after a bubble had been produced, thus heightening the accuracy.

Overall, I felt that due to the small volumes of oxygen involved, my experiment was not as accurate as it could have been, however I believe it was accurate enough to support and justify my hypotheses. Improvements could have been made as I have stated, mainly by simply increasing the time taken. However, due to practical time constraints in taking the readings for my investigation, and some consequential problems relating to time extension, I could not in fact make these adjustments. The other obvious way of increasing the reliability of my results would be to take many repeat readings and find an average.

To extend my enquiries into the rate of photosynthesis, I could perhaps try to link in some of the other limiting factors to the same experiment, as well as investigating them in their own right. It could also be interesting to explore the effects of coloured lights on the rate of photosynthesis, which 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.