An experiment to see how light intensity affects the photosynthesis of a plant.

Introduction

The aim of this experiment is to determine whether or not the intensity of light will affect the rate of photosynthesis in a plant. In order to do this, I will place pondweed in different light intensities, and observe the amount of oxygen that is given off.

Hypothesis

I predict that as the intensity of light increases, so will the rates of photosynthesis. Furthermore, if the light intensity increases the rate of photosynthesis will increase at a steady rate until a certain 'peak' is reached, and then the rate will no longer increase.

Photosynthesis will only occur in the presence of light. It takes place in the chloroplasts of green plant cells. It can be defined as the production of simple sugars from carbon dioxide and water, which causes the release of sugar and oxygen. The chemical equation for this is the following:

The reason that light intensity will affect the rate of photosynthesis is because as the light (energy) falls on the chloroplasts in the leaf, the chlorophyll traps the light, which will then make the energy from the light available for chemical reactions to take place in the plant. Therefore, if the amount of light is increased, from the bulb in this case, the light energy is absorbed and more energy is available, thus more photosynthesis is able to take place in a set time.

Though there are factors that can affect the rate of photosynthesis which include temperature, carbon dioxide concentration and light intensity. The optimum rate of photosynthesis will be constrained by a limiting factor. This limiting factor will prevent the rate of photosynthesis rising above a certain level, even if you improve the other conditions needed for photosynthesis to take place. It will therefore be necessary to control these limiting factors during the experiment so as not to let this affect my results.

Apparatus

Beaker of water, pondweed, lamp, heat sink, stopwatch, thermometer, tripod stand (to place beaker on).

Method

Fill a beaker with 80 ml of water, place the pondweed inside the beaker, and then insert a thermometer into the beaker in order to record the temperature at the start and end of the experiment, as a precaution against any significant temperature rise that is not to be expected. Set up the lamp at a set distance from the plant, making sure that the distance is between the filament of the lamp to the actual pondweed, and not the beaker. When bubbles start to appear at a steady rate, start the stopwatch and wait for 30 seconds. Record the

amount of bubbles, then wait for another 30 seconds, record, and so forth until you have obtained all other readings. Then repeat all the readings a second time in order to obtain an average result for each distance.

The variables I will change are the input and the output variables, the input being light intensity and the output being the volume of oxygen that is produced. Light intensity will be varied by increasing and decreasing the distance from the light source (the lamp) to the pondweed. The volume of oxygen produced (the rate of photosynthesis) is to be measured by finding the amount of oxygen bubbles, and therefore finding the rate of photosynthesis.

I will also need to control certain variables. I will control light colour wavelength as light energy is absorbed by chlorophyll in the leaf. Chlorophyll easily absorbs red and blue light, but however it doesn't easily absorb green or yellow light, instead it reflects them, thus decreasing the amount of light absorbed, and hence the rate of photosynthesis. Though, simply using the same lamp throughout the experiment can easily control this.

Chemical reactions, including photosynthesis, in plants, like all living things are controlled by enzymes. Therefore temperature will increase the rate of photosynthesis, until a point at which the enzymes denature (around 45 C). Tough I am going to perform the experiment at room temperature, instead of keeping it at a constant temperature, and read the temperature frequently to see if the heat given off from the light should slightly raise the temperature, and in that case I will just refill the beaker with more water after the experiment.

Carbon dioxide can affect the rate of photosynthesis, since if there is too little carbon dioxide, it can become a limiting factor, and affects the experiment. Though 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 won't be sufficient enough for it to become the limiting factor. If my experiment were to be drawn out over a long period of time, then I would need to add something like sodium hydrogen carbonate to the water so that there would be a large enough supply of carbon dioxide.

Water is also required in photosynthesis, and when there is a lack of water, the plant's stomata closes to prevent any further water loss. The closing of the stomata cells also leads to little carbon dioxide diffusing through. Though clearly, if the plant is fully submerged in water at all times this will not be a problem.

Preliminary work

I have done a preliminary experiment, which I carried out in Year 9 Biology, in which I recorded the number of oxygen bubbles given off in a given time, at different light intensities. These are the following results I obtained:

This was a quick and simple experiment, and an efficient way of obtaining a rough idea of the trends for the graph, and an idea for the boundaries of my measurements for the light. Though I do not think that this experiment would be accurate enough to use it for the basis of my main experiment. This could be less accurate as there was light coming from the window and there was lighting in the window. In this experiment I will carry out, I hope to close the blinds in the room and not have the lights on, so the exterior light is not affecting my results. Though the preliminary experiment will, however, show me whether light intensity has any effect or not at all. In this case it has had an effect, and this preliminary experiment supports my hypothesis that as the light intensity increases, as the lamp gets closer to the plant, the rate of photosynthesis, shown by the amount of bubbles produced, increases as well. The experiment also shows that in order to obtain more readings, I should have a shorter time interval for each measurement of oxygen bubbles.

Analysis

I drew my graph with a line of best-fit curve. I did this instead of a straight line because of the clear pattern of the points on the graph. My graph shows me that an increase in light intensity will certainly increase the rate of photosynthesis. Both my graphs and my results support my hypothesis fully. The prediction I made that, as the light intensity increases so will the rate of photosynthesis, was backed up with the results I obtained in this experiment. This is because photosynthesis will only occur in the presence of light. It takes place in the chloroplasts of green plant cells. It can be defined as the production of simple sugars from carbon dioxide and water, which causes the release of sugar and oxygen. The chemical equation for this is the following:

The reason that light intensity affected the rate of photosynthesis is because as the light (energy) falls on the chloroplasts in the leaf, the chlorophyll traps the light, which then makes the energy from the light available for chemical reactions to take place in the plant. Therefore, because the amount of light was increased, from a bulb in this case, the light energy was absorbed and more energy was available, thus more photosynthesis was able to take place in a set time.

The gradual decrease in the increase of the rate of photosynthesis (the curve becoming less steep and more constant) can be traced to the other factors that limit the

rate of photosynthesis. As the light intensity is increased, the rate of photosynthesis is being limited by certain factors, such as carbon dioxide or temperature. Although these factors will not limit the rate of photosynthesis straight away, instead they will do it rather gradually. Thus as the light intensity is increased further, the rate of photosynthesis is further limited by other factors, until the rate of photosynthesis becomes constant, and it is probably then limited in full by another factor.

Evaluation

Overall I felt that the experiment was reliable, although there were certain things at which the accuracy was not perfect. As I have already mentioned in my plan, the preliminary experiment I used was not accurate enough to justify being used as my main experiment, mostly due to the fact that I didn't have big enough range of results to obtain an average in order to be more accurate. It was also the distances away from the light that I used as my input variable, instead of the actual light intensity measurement that I would need to use in my main experiment.

The distance between the pondweed and the light source were not measured to the highest degree of accuracy, particularly when you consider the fact that the distance should have been measured exactly from the centre of the plant to the filament of the light bulb, and it is possible to find an error here, which could have been up to about 0.5 cm. Although I was not actually using the distances as part of my results, I instead used them as a marker for where I would place the pondweed each time, and then work out the light intensity using the following equation: intensity $= \frac{100}{d^2}$ where d is representing distance. Hence any inaccuracies that occurred in measuring the distances, an error would arise.

Probably the second main inaccuracy was in measuring the amount (volume) of oxygen given off- due to the fact that I was relying on all the bubbles produced being the same size, which they clearly weren't. I think it would have been perhaps more accurate if I had used a gas syringe to measure the volume of oxygen produced. This would have been more accurate but due to limited resources, realistically it was not feasible.

Another error would have been due to background light coming from the room and also from the outside via the windows. We tried to reduce this problem by closing the blinds in the room, but we couldn't all perform our experiments in separate rooms, and thus we experienced other light from other student's experiments. Although this would have only had a very marginal effect on my results, but for future solutions to eliminate this problem completely I would have to perform this experiment in a room that was totally dark. The heat generated from the lamp is a further inaccuracy, as I have previously mentioned in my plan, temperature has a very noticeable effect on the rate of photosynthesis as it is a limiting factor, so any increase in temperature of the water would have an effect on the accuracy of my results. In order for this not to happen I took the temperature before and after each reading, to check the temperature hadn't risen. Though this turned out not to be a problem, as my experiment only took a short period of time, where the temperature did not rise at all. But still as a precaution I used a water bath as a heat sink to prevent a temperature rise by absorbing the heat, while still allowing the light energy to pass through.

Earlier on in my plan I mentioned that carbon dioxide concentration could have been an error in my experiment but because the experiment only took over a short period of time I feel that there is little chance that the concentration became so low that it became the limiting factor. If I were to carry out the experiment again over a longer period of time, in order to obtain more readings, it would then be necessary to add sodium hydrogen carbonate to the water so the carbon dioxide concentration would be increased. In my result tables, one table had a higher rate of oxygen bubbles produced than the other, and this is due to the fact I used different pondweed the second time, so carbon dioxide levels would not have been the same.

Due to the small volumes of oxygen produced, my experiment was perhaps not as accurate as it could have been though I still think it was accurate enough to justify and support my hypothesis. I could improve the experiment by simply increasing the time taken, so fewer errors are able to occur. I could not make this adjustment due to time constraints.

To extend my investigation into rate of photosynthesis further, I could try investigating other limiting factors individually, as well as perhaps trying to link in some of the other limiting factors with my current experiment. Further investigation into the light factor could be exploring the effect on the rate of photosynthesis by different coloured lights, which could also lead to whether any other types of lights, like fluorescent lights, would also have a different effect on the rate.