Mohammed Ismail Ayub Biology experiment

How light intensity and temperature affects the rate of photosynthesis

Aim

The aim of my experiment is to determine whether intensity of light and temperature would affect the rate of photosynthesis in a plant. To do this, I will place a piece of pondweed in varying light intensities and temperatures, and observe the amount of oxygen being given off. I am using pondweed because of its unusual quality of giving off bubbles of gas from a cut end, when placed in water.

Introduction

Photosynthesis occurs only in the presence of light, and takes place in the chloroplasts of green plant cells. Photosynthesis can be defined as the production of simple sugars from carbon dioxide and water causing the release of sugar and oxygen.
The chemical equation for photosynthesis can be expressed as:

(light)

$$6CO_2 + 6H_2O \text{-------------} C_6H_{12}O_6 + 6O_2$$

(In the presence of chlorophyll)

The word equation:

Carbon dioxide + Water------------ Glucose + Oxygen

The fact that all plants need light in order to photosynthesise has been proven many times in experiments, and so it is possible to say that without light, the plant would die. The reason that light intensity does affect the rate of photosynthesis is because light is the source of energy which, falls on the chloroplasts in a leaf and is trapped by the chlorophyll, which then makes the energy available for chemical reactions in the plant. Thus, as the amount of sunlight, or in this case light from a bulb, falls on the plant, more energy is absorbed, so more energy is available for the chemical reactions, and so more photosynthesis takes place in a given time.
There are many factors, which affect the rate of photosynthesis, including light intensity, temperature and carbon dioxide concentration. The maximum rate of photosynthesis will be constrained by a limiting factor. This factor will prevent the rate of photosynthesis from rising above a certain level, even if the other conditions needed for photosynthesis are improved. It will therefore be necessary to control these factors throughout the experiment so as not to let them affect the integrity of my investigation into the effect of light intensity and temperature.

Predictions

I predicted that as the intensity of light and temperature is increased, so would the rate of photosynthesis. Furthermore, I hypothesised that if the light intensity and temperature 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 and the temperature will reach a position were the enzymes will denature because the intensity of temperature and no photosynthesise will occur or there will be another limiting factor, in this case probably carbon dioxide.

Fixed Variables-

Light Wavelength (color)- Light energy is absorbed by pigments in the leaf such as chlorophyll. Chlorophyll easily absorbs blue light, in the 400 -450 nm range, and also easily absorbs red light in the 650-700 nm range. Chlorophyll does not absorb green light or yellow light effectively but tends to reflect them, decreasing the amount of light absorbed and decreasing the rate of photosynthesis. Why the rate of photosynthesis increases or decreased from the amount of light energy absorbed is what is being investigated in this experiment. The light color can be fixed by using the same lamp throughout the experiment.

Carbon Dioxide- CO_2 concentration can affect the rate of photosynthesis since the more CO_2 in the air, the more CO_2 that can diffuse into the leaf. This variable can be fixed by adding a fixed amount of sodium hydrogen carbonate to the beaker and plant. The experiment should also be completed in one session and under two hours so the plant does not use up a significant percentage of the CO_2.
Water- Water is required in the photosynthetic reaction. When plants lack water, their stomata close to prevent further water loss. At the same time, closing the stomata cells doesn't allow CO_2 to diffuse into the leaf. Water is also therefore, linked to the carbon dioxide factor. Water can be kept a constant by keeping the same amount of water in the beaker.

Temperature- Enzymes are used in photosynthesis and the respiration of the plant. Therefore, increasing the temperature will increase enzyme reaction and the photosynthetic rate until a certain point is reached when the enzymes denature. The temperature can be kept somewhat a constant by performing the experiment in one session, when the air temperature shouldn't change enough to affect water temperature. A transparent glass block will also be placed in front of the lamp to retain some of the heat from the lamp.

Plant- Different species plants have different photosynthetic rates due to the different leaf structures of the plants. Even plants of the same species may have slightly different rates of photosynthesis since there may be more or less chlorophyll in the leaves to absorb light. The size of the plant is also important since this would affect the amount of surface area for gas exchange. The only solution to controlling this variable is by using the same plant throughout the experiment.

Limiting Factors- Light, carbon dioxide, temperature, and chlorophyll are all limiting factors, meaning that even when there is surplus of every other variable, the rate of photosynthesis will be limited by the limiting factor until there is an optimal amount of the limiting factor to increase the rate of photosynthesis further. Otherwise, the rate of photosynthesis can no longer increase.

Apparatus
Ruler
pond weed
Knife
Clamp
Pond water
Thermometer
Test-tube
Beaker
water
Stopwatch

Ice
Bunsen burner

Diagram

Method

- Set up the apparatus as shown in the diagram above.
- Fill the beaker with water at the right temperature
- Select the pondweed and make sure it will fit in the beaker and cut little of the stem from below
- Place the pond weed in the beaker making sure its covered with the water and no part of the pond weed is submitted to the air
- Place the lamp directly in front of the plant so that the light is shining towards the plant and then move the beaker at correct length using a ruler
- With the light shining on the plant, record the number of bubbles emitted in a 2-minute duration and takes these results for 10 minutes.
- Repeat the test by using water with temperature of 15c,24c and 35c with lamp shining from the lengths one meter, 50cm and 25cm

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 100 1 (mm/min) same factor) 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:

Overall, I would state the experiment as a success since my predictions were supported by my results. This is important in reflecting success only if my prediction was sensible and logical. Just as important is where the experiment was not a success and why. 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 pondweed did not photosynthesise at a steady rate, even when the distance from the plant to the light source was kept a constant.

The second reading at 0 cm was far greater than the first reading at 0 cm. While the number of oxygen bubbles was being recorded, the rate at which the plant was photosynthesising had increased several times. This may be due to the poor circulation of sodium hydrogen carbonate at the beginning of the experiment. Carbon dioxide may have initially limited the rate of photosynthesis. The readings at 0 cm and 5 cm were repeated many times until the rate of photosynthesis had begun to settle. From then on, there were no more similar problems during the experiment.

To make sure that the there
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 0 cm or only 5 cm.

A large factor in determining data accuracy is the amount of human error during experiments. The rate at which oxygen bubbles were being produced by my plant was high which meant I found it difficult to count the amount of bubbles. I estimate a margin of error of at least 3 bubbles for each reading taken. To improve the accuracy of the results, the readings would have to be taken several more times. The entire experiment could have been performed again, and the new results could be combined if the same plant is used. But the photosynthetic rate of the same piece of pondweed would eventually decrease over time anyway. Repetitions would, however, improve the overall reliability of the results.

There are quite a few factors that could affect the results of my experiment. Some of these are variables that were mentioned earlier and could not be controlled, or they were variables that were not initially considered.

While performing the experiment, some of the oxygen produced from photosynthesis may have dissolved into the water. Some oxygen may have even been used by micro-organisms living on the pond weed. The amount of oxygen dissolved or used by microbes is probably insignificant to my results since the degree of 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 to 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 analyzed. 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.

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 pond weed receives some light energy from background light such as sunlight seeping through curtains or the light from the lamp of another student's experiment. To eliminate most all background light, the experiment must be performed in a completely dark room. Even then, some of the light from the lamp in my experiment would reflect of the table and reach the plant though this amount of light is probably insignificant in affecting the rate of photosynthesis.

Temperature was also another factor that was controlled by the lamp being used. Even though a glass block was used in front of the lamp to prevent some heat from reaching the plant, not all the heat can be blocked. The extra heat, however, did not affect the temperature of the water, which stayed at between 290 and 300 C.

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 pond weed, 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. If the capillary tube option was to be chosen, volume should be measured for a smaller time frame to reduce the overall time to complete the experiment. Also, during high rates of photosynthesis, it would still be difficult and impractical to measure the volume of oxygen produced for a long duration.

Due to the nature and convenience of the experiment, it could be easily modified to investigate another variable of photosynthesis. Since sodium hydrogen carbonate ($NaHCO_3$) is used to provide the pondweed with carbon dioxide. Performing the experiment with different volumes of $NaHCO_3$ could vary the amount of CO_2. The plant would be kept at a constant distance from the lamp and a constant volume of water would be added to the sodium hydrogen carbonate. Another experiment using almost identical apparatus would be to vary the color of the light the plant absorbs. Using translucent color filters in front the lamps could vary this. Since light wave length has already been identified as a variable of photosynthesis, it would be interesting to actually test it. The only problem of this experiment is that there is no way to define or "measure" the color of light. Wave length would be a solution but this cannot be measured with available equipment. We only have a general idea of how to class colors. Because of this, the colored light experiment should not be taken as seriously as light intensity or carbon dioxide.