Photosethesis

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Aim:

To investigate a factor that affects the rate of photosynthesis.

Outline:

A piece of pondweed will be cut and placed into a beaker containing water and sodium hydrogen carbonate. A lamp will be shined on to the pondweed and the amount of bubbles released from the plant will be counted. The lamp will be adjusted to different distances from the plant to try and obtain different results.

Photosynthesis Equation:

$CO_2 + H_2O$ light energy & chlorophyll $CH_2O + O_2$

Variables:

Experimental Variable- Light intensity is to be the variable explored in this investigation. Increasing or decreasing the distance from the light source to the plant can vary light intensity.

Fixed Variables:

Light Wavelength (colour)- Light energy is absorbed by pigments in the lea f 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 colour 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 CO2 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.

Prediction:

I predict that increasing the light intensity will increase the rate of photosynthesis at a proportional rate where LI is inversely proportional to 1/d2 when LI= light intensity and d= distance (from light source to plant). This is true to a certain point until another factor is limiting the rate of photosynthesis.

Hypothesis:

When chlorophyll absorbs light energy, the light energy cannot be immediately used for energy conversion. Instead the light energy is transferred to a special protein environment where energy conversion occurs. This happens by using the energy of a photon to transfer electrons from a chlorophyll pigment to the next. When enough light energy has been harnessed at a reaction centre, ATP can be synthesized from ADP. During this reaction, oxygen is produced as a by-product and it is the oxygen bubbles that are being measured in the experiment. The greater the light intensity, the more light energy that can be transferred and harnessed to fuel reaction in photosynthesis.

Light intensity is inversely proportional to the distance squared because the light energy spreads out as it travels further and further from its source. Light energy travels along the circumference of an expanding circle. When light energy is released from a point, the energy is dispersed equally along the circumference. But since the circle is expanding, the circumference increases and the same light energy is distributed along a greater surface.

Method:

1. Set up the apparatus as shown in the diagram above but leaving out the pondweed, funnel, test tube, water, and the sodium hydrogen carbonate.
2. Fill the beaker with 450 cm3 of water and 50 cm3 of NaHCO3.
3. Select 1 or 2 pieces of pondweed each roughly 5 -10 cm long and cut off the stems.
4. Place the pondweed in the beaker and secure the funnel upside down over (on top of) the pond weed using the plastacine .
5. Place a water-filled test tube upside down and over the funnel (see diagram).
6. Place the ruler so that the "0" measurement is aligned with the side of the beaker. (Distance measured from side of beaker to edge of light bulb)
7.) Place the lamp directly in front of the plant so that it is 0 cm away from the beaker. 8.) With the light shining on the plant, record the number of bubbles emitted in a 1 minute duration. Switch off the lamp and wait for another minute before taking another reading.
9.) Take 3 readings at the current distance and move the lamp 5 cm further away from the plant.
10.) Repeat steps 8 and 9 until 3 readings from at least 5 intervals of 5 cm have been taken.
11.) Proceed to the data analysis stage.

Results:

The temperature of the water stayed a constant at about 29.5O ^{c} throughout the experiment.

Conclusion:

From the results that I have gathered I can state that an increase in light intensity certainly does increase the rate of photosynthesi s. As was also expected in my prediction, the relationship between light intensity and the rate of photosynthesis was non-linear. From both graphs there is a best-fit curved line. This means that the rate of photosynthesis increases at an exponential rate.

However, my prediction that light intensity is inversely proportional to the distance squared did not fit into my results perfectly. The rule existed but there was often quite a large margin of error.

When measuring light intensity in term s of distance, the greater the distance, the slower the rate of photosynthesis. While the rate of photosynthesis was decreasing, the rate at which it was decreasing at was also decelerating. This is where the line in graph 1 shallowed.

When measuring the light intensity in terms of LUC, the greater the distance, the slower the greater the rate of photosynthesis. While the photosynthetic rate increased, the rate at which it increased was decreasing. This is where the line in graph 2 shallows.

The shallowing of the line in graph 1 can be explained by the fact that light intensity is inversely proportional to the distance squared. This means

that as distance increases the light intensity decreases at an exponential rate. If light intensity decreases exponentially, photosynthetic rates that depend on light intensity also decreases exponentially. The line in graph 1 would eventually reach "0" where photosynthesis stops as light intensity limits this rate.

The shallowing of the line in graph 2 is due to other factors limiting the rate of photosynthesis. These other factors do not immediately limit the rate of photosynthesis but rather gradually. 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 become horizontal. This is when photosynthesis is being carried out at a constant rate.

The reason that a "f 1/b2 did not apply was due to the apparatus used. The lamp that I used had a cover that directed the light energy somewhat. The light energy did not spread out as much as a plain light bulb with no cover. The distribution of the light energy was more concentrated, changing the gradient of the graph.

Evaluation:

Overall, I would state the experiment as a success since my predictions were supported by my results. This is important in reflecting succe ss 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 so high that 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 pond weed 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.