Photosynthesis Investigation

Aims:
I plan to investigate how different factors affect the rate of photosynthesis.
Background Information:
The rate of photosynthesis is affected by a number of factors including light levels, temperature, availability of water, and availability of nutrients. If the conditions that the plant needs are improved the rate of photosynthesis should increase.

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 other conditions needed for photosynthesis are improved. This limiting factor will control the maximum possible rate of the photosynthetic reaction.

For instance, increasing the temperature from 10ºC to 20ºC could double the rate of photosynthesis, as the plant's enzymes will be closer to their optimum working temperature. As the temperature is increased, molecules in the cells will be moving at a faster rate due to kinetic theory. If the temperature is raised above a certain level, the rate of photosynthesis will drop as the plant's enzymes are denatured. They will therefore be more likely to join onto the enzymes and react.

The amount of water available to the plant will affect the rate of photosynthesis. If the plant does not have enough water, the plant's stomata will shut and the plant will be deprived of CO2. It is difficult in normal lab conditions to prove that water directly affects photosynthesis unless a heavy isotope is used to trace the path of water.

Chlorophyll is needed for photosynthesis. Studying a variegated leaf can prove this. It is however very difficult to study how different levels of chlorophyll in the plant will affect it's photosynthesis rate. This is because in a variegated leaf the cells either contain chlorophyll or they don't.

Carbon dioxide concentration will directly affect the rate of photosynthesis as it is used in the photosynthesis reaction. It is also easy to change the amount of carbon dioxide that the plant receives.

Light is also directly used in the photosynthesis reaction and is easy to change in normal lab conditions. Carbon Dioxide and Light are the factors that I will change in the experiment, as they are easy to change and measure.

Apparatus Needed For The Experiments:
Elodea
20mm2 syringe
Capillary tubing
Stand
Stopwatch
Ruler
NaHCO3 Solution
Bench lamp
Distilled water
Method

I could measure the decrease in the substances needed for photosynthesis, such as how much the amount of CO2 decreases over time. This is however difficult in normal lab conditions. I will instead measure how one of the products of photosynthesis (oxygen) increases over time. I am planning to use the following method for my experiment.

The apparatus is set up as below with the syringe full of the 0.01M solution of NaHCO3 solution. Two marks 10cm apart are made on the capillary tubing.
The syringe is placed 0.05m away from the lamp.
Using the syringe plunger the meniscus of the NaHCO3 is set so that it is level with the first mark.
A stopwatch is then started. The meniscus should gradually move down the capillary tube as the elodea produces oxygen as a by-product of photosynthesis. As the oxygen is produced it increases the pressure in the syringe and so the meniscus is pushed down the tube
When the meniscus reaches the level of the bottom mark the stopwatch should be stopped and the time should be noted in a table.

The light intensities have been worked out using the following equation

Light Intensity = 1 / Distance2 (m)

6. Using the same piece of elodea and the same distance between the lamp and the syringe the experiment (steps 1 to 5) should be repeated for the other concentration of $NaHCO_3$.
7. The experiment (steps 1 to 6) should then be repeated at each different distance betweenthe syringe and the light for all the $NaHCO_3$ concentrations. The remaining distances are 0.05m, 0.06m, 0.07m, 0.08m, 0.1m, 0.2m, 0.3m, and 0.5m.
8. The entire experiment should then be repeated three times in order to obtain more accurate data and to get rid of any anomalies that may occur in a single experiment.

Measuring the volume of oxygen is more accurate than counting the number of bubbles produced, as each bubble could be a different size. In order to make this experiment as accurate as possible a number of steps must be taken.

The experiment should be carried out in darkness with only the light from the bench lamp reaching the elodea.
The same piece of elodea should be used each time in order to make sure that each experiment is being carried out with the same leaf surface area.
The amount of $NaHCO_3$ solution should be the same for each experiment. 20mm2 should be used each time.
The lamp should be at the same height for each experiment. It should be level with the syringe each time.
The distance should be measured from the front of the lamp to the syringe. Although taking these steps will make the experiment more accurate, it's accuracy is still limited by several factors.
Some of the oxygen will be used for photosynthesis by the plant.
Some of the oxygen will dissolve into the water.
From these recorded times I will work out the rate of the reaction using the following equation.

Rate Of the Reaction = 1 / Time (s)

Using these rates I plan to plot a graph of the rate of reaction against light intensity.

Predictions

Light

I predict that if the light intensity increases the rate of the reaction will increase at a proportional rate until a certain level is reached, the rate of increases will then go down. Eventually a level will be reached where increasing the light intensity will have no more effect on the rate of reaction, as there is some other limiting factor.

Light is needed for photosynthesis in plants. When chloroplasts in the leaf's cell are exposed to light they synthesise ATP from ADP. Oxygen is produced as a by-product of the photosynthesis reaction. Therefore increasing the concentration of light will increase the amount of ATP being synthesised from ADP and so more oxygen will be released as a by-product.
$NaHCO_3$

I predict that as the concentration of $NaHCO_3$ increases the rate of the reaction will increase at a proportional rate. Eventually increasing the $NaHCO_3$ concentration more will have no effect, as other limiting factors will be limiting the rate of photosynthesis. Carbon dioxide is needed for the photosynthesis reaction. It is used to make the organic products of photosynthesis. If the elodea is able to absorb more CO_2 then the rate of photosynthesis will increase, as the plant is able to make more of the organic compounds. The plant is given CO_2 in the form of $NaHCO_3$.

Results

Rate Of the Reaction = 1 / Time(s) x 1000

the rate was multiplied by 1000 to make the numbers easier to handle.

A graph of the rate of reaction against light intensity was drawn. It shows how the amount of CO_2 and light affect the rate of photosynthesis. Lines of best fit were drawn for each CO_2 concentration to make up for any inaccuracy in any individual result. The line of best fit gives a good picture of how the overall rate of reaction is affected by the light and CO_2.

Interpretation

I will analyse the results for how the amount of light and CO_2 affects the rate of photosynthesis.

My prediction that the rate of photosynthesis would go up if the light intensity and $NaHCO_3$ levels were increased proved correct. As the elodea absorbed the light and CO_2 it produced oxygen gas, which increased the pressure in the syringe. This pushed the air bubble in the capillary tube down. The chloroplasts produce ATP and reduce NADP to $NADPH_2$ when exposed to light. It is at this stage of the reaction that oxygen is produced as a waste product.

As predicted when the light intensity increases so does the rate of photosynthesis. I predicted that a level would be reached where increasing the light intensity would have no more effect on the rate of reaction, as there would be some other limiting factor, which limits the rate of the reaction. The rate increases at a steady rate as the light intensity increases until near the end of each line where the rate of increase decreases. This is either because the photosynthesis reaction has reached its maximum rate of reaction or another factor is limiting the rate. As 6 different CO_2 concentrations were used I can see that the first five reactions are not occurring at their maximum rate, as there is the 0.1M $NaHCO_3$ rests which is occurring at a faster rate then the other 5. The photosynthesis reactions of the other five tests must therefore be limited by the concentration of CO_2 to the plant.

As predicted when the $NaHCO_3$ concentration is increased the plant in able to get more CO_2 which causes the rate of reaction to go up. I predicted that once the $NaHCO_3$ had been raised above a certain level increasing the rate further would have no effect, as there would be other limiting factors limiting the rate of the reaction. As the $NaHCO_3$ concentration in the water was increased the rate of photosynthesis was able to go up. The plant therefore made more oxygen as a waste product. At a $NaHCO_3$ concentration of 0.1M once the light intensity gets above 300 the rate of reaction slows down very quickly. This could be because photosynthesis is occurring at its maximum possible rate or because another limiting factor is limiting the rate of reaction.

Distilled Water

With the distilled water the rate of reaction went up from 0.1 to 0.4 when the light intensity was increased from 100 to 400. This is a 4 times rise which is quite large. The curve on the graph does however level out quite soon showing that the rate is being limited by the lack of $NaHCO_3$ in the water.

0.01M $NaHCO_3$

at a light intensity of 4 the rate is 0.06 but this rises to 0.6 when the light intensity is brought up to 400. The curve is very shallow and levels off towards a light intensity of 350 - 400.

0.02M $NaHCO_3$

the amount of $NaHCO_3$ is double that of the 0.01M $NaHCO_3$ experiment. The rate also finishes off twice that of the 0.01M experiments. This would suggest that there was a directly proportional relationship between the amount of $NaHCO_3$ and the rate of reaction.

0.05M $NaHCO_3$

the curve for the 0.05M $NaHCO_3$ is steeper than the previous curves. The rate rises to 1.9 at a light intensity of 400.

0.07M $NaHCO_3$

The 0.07M $NaHCO_3$ test produces a line, which is steeper than all the previous curves. The plant is using the extra CO_2 to photosynthesise more. As the plant has more CO_2 the limiting factor caused by the lack of CO_2 is reduced. This test did produce a big anomaly. The rate for a light intensity of 400 is 5. By following the line of best fit I can see that this result should be more like 3.5. The elodea for this test was very close to the light source. It is possible that it had been left here for a while which caused the lamp to heat the elodea up. This would have increased the rate of reaction of the plant's enzymes, which would have increased the photosynthesis rate.

0.1M $NaHCO_3$

The 0.1M $NaHCO_3$ produced the steepest line. Near the end of the line it looks as if the rate of reaction is hit by another limiting factor. The line goes up steadily but then between a light intensity of 300 and 400 levels off very quickly. This would suggest that at a 0.1M $NaHCO_3$ is sufficient for the plant to photosynthesise at its maximum rate with its current environmental conditions. Increasing the $NaHCO_3$ concentration after this level would therefore have no effect unless the next limiting factor was removed.

The fact that the curve levels off so quickly indicates that there is another limiting factor limiting the photosynthesis. It could be temperature. These tests are being carried out at room temperature so the temperature would have to be raised another 15ºC before the enzymes in the plant's cells were at their optimum working temperature. Using water that was at a higher temperature to see what effect this would have on the photosynthesis rate could do more tests. It is however impossible to raise the plant's temperature without affect other factors. For instance the actual amount of oxygen released by the plant is slightly more than the readings would suggest as some of the oxygen would dissolve into the water. At a higher temperature less oxygen would be able to dissolve into the water so the readings for the photosynthesis rate could be artificially increased.

It is also possible that the photosynthetic reactions in the plant are occurring at their maximum possible rate and so cannot be increased any more.

The light is probably not a limiting factor as all but one of the curves level off before the maximum light intensity of 400 is reached. The maximum light intensity that the plants can handle is therefore just below 400.

Water will not be a limiting factor as the plants are living in water. They therefore have no stomata and absorb all their CO2 by diffusion through the leaves.

Limitations:
The accuracy of this experiment is limited by a number of factors.

Some of the oxygen give off is used for respiration by the plant.
Some of the oxygen dissolved into the water.
Small invertebrates that were found living within the pieces of elodea used some.
The higher light intensities should be quite accurate but the smaller light intensities would be less accurate because the light spreads out. The elodea will also get background light from other experiments.
The lights are also a source of heat, which will affect the experiments with only a small distance between the light and the syringe. This heating could affect the results.
Using the same piece of elodea for each experiment was impractical as the elodea's photosynthesis rate decreased over time. By using a different piece of elodea for each experiment did create the problem of it being impossible for each piece to have the same surface area.
As the tests took place over a two-day period there will be some inaccuracy caused by factors such as temperature. There was no practical way for the long tests to be kept at a totally constant temperature for the two day period and they will probably have cooled down at night and then warmed up in the day leading to a slight inaccuracy.
Extension Work

This experiment could be improved in a number of ways.

It could be repeated more times to help get rid of any anomalies. A better overall result would be obtained by repeating the experiment more times because any errors in one experiment should be compensated for by the other experiments.
Each person should have done his or her experiments in a different room to cut out all background light.
All the experiments should be done sequentially.
A Perspex screen could have been placed between the light and the syringe to reduce any heating effect that the light may have.
The experiment could have been carried out with higher NaHCO3 to see if increasing the concentration would increase the rate of photosynthesis, or if a concentration of 0.1M NaHCO3 produces the maximum rate of photosynthetic reaction.