Investigation into how light intensity affects the rate of photosynthesis

Aim:
The aim of this investigation is to determine whether light intensity affects the rate at which plants photosynthesise.

Introduction/Prediction:
All living things need food to survive. Photosynthesis is the chemical process, which takes place in every green plant to produce glucose, the plants food supply. Glucose is used for many different things in the plant; it can be combined with nitrates from the soil to make amino acids, which then in turn can be used to make proteins. Glucose can be turned into cellulose which is used to make strong cells that can support the plant keeping it up right. But most importantly glucose is needed in the growing parts of the plant i.e. shoots, roots, developing buds, flowers and fruits. These areas of the plant need the sugars as a source of energy and as materials in the growth.

The chemical equation for photosynthesis is:

$$\text{Carbon dioxide} + \text{Water} \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} \text{Glucose and Oxygen}$$

$$6CO2 + 6H2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C6\ H12\ O6 \text{ and } 6O2$$

Sunlight is trapped by a green pigment called chlorophyll in the chloroplast cells of the leaf. The chlorophyll then turns the light energy it trapped from the sun into chemical energy which is used to join together water and carbon molecules to make glucose (a sugar); oxygen is also produced as a by-product. This glucose can be transported up and down the plant by the phloem (one of the plants veins that transports sugars up and down the stem) to where it is needed.

If all the glucose is not needed all at once then some of it can be stored until it is needed. Glucose is not an easy substance to store as it is soluble and would cause water to get into the storage cells in the roots, causing them to swell up by osmosis (the movement of water through a semi-permeable membrane) and burst. So instead the plant turns the glucose it does not need into starch, which is insoluble and can be easily stored with out osmosis occurring. This starch can then be used when there is little sunlight around, especially in the winter months.

Oxygen is also made as a by-product of photosynthesis; some of this oxygen is diffused out of the plant through the stomata a small amount of oxygen is kept and used by the plant in respiration (used to make energy for other functions in the plant).

The plant is well adapted for making glucose through photosynthesis. Its thin, broad structure gives a large surface area for absorbing as much sunlight as possible. The think waxy cuticle on the surface of the leaf gives a waterproof layer preventing water loss from the leaf. The palisade cells which are packed full of chloroplasts are found near the top of the leaf where they can absorb all the suns light. On the underside of the leaf there are tiny holes called stomata which let carbon dioxide and oxygen diffuse in and out of them which is essential in photosynthesis. In addition they also control how much water is let in and out of the plant, also essential in photosynthesis.

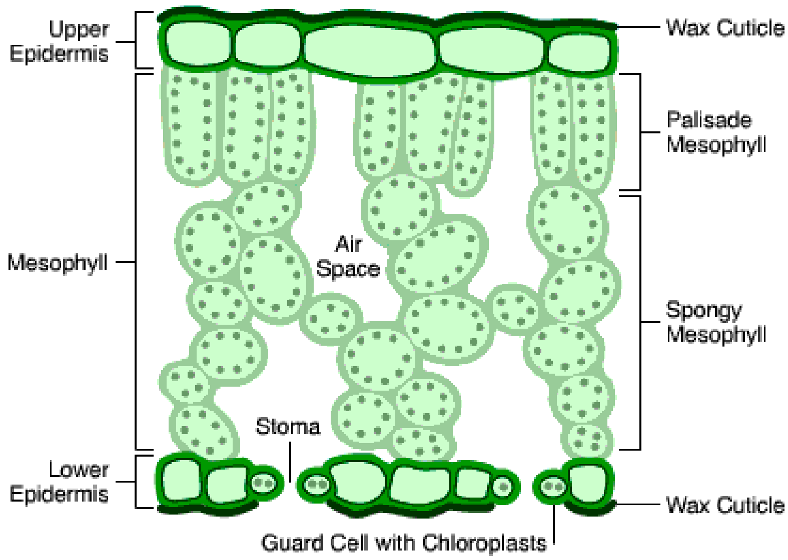

Diagram of a cross-section of a leaf.

For photosynthesis to be successful, there are 4 main things the plant needs. They are: Carbon dioxide, Water, light and chlorophyll.

Carbon dioxide
Carbon dioxide enters the leaf through the stomata cells on the underside of the leaf. The layers of palisade and spongy mesophyll cells are full of air pockets; these spaces allow the carbon dioxide to diffuse into the palisade cells and on into the chloroplasts where it can be joined with oxygen to produce glucose.

Water
Water is obtained through the root hair cells in the root of the plant. These cells suck up all the water and nutrients from the surrounding soil to be used by the plant. If the plant did not have water it would not be able not be able to survive and just like all other living things would die. Water is also important because it is needed to join with the carbon dioxide to make glucose.

Sunlight
Sunlight is used as an energy source. It is absorbed by the chlorophyll in the chloroplast cells and changed into chemical energy and used to join carbon dioxide and water together to produce glucose. So in the winter months when there is very little sunlight the plant must rely on its stores of starch to keep it going. Sunlight is also used to keep the plants temperature constant. Chlorophyll is an enzyme so will not work if the temperature is too hot or too cold so sunlight is used to keep the temperature constant.

Chlorophyll

Chlorophyll is important in photosynthesis because it is the pigment that absorbs the sunlight, without it no sunlight would be absorbed and thus there would be no chemical energy to join the carbon dioxide and water molecules, so there would be no glucose crated and the plant would die. Chlorophyll only absorbs the red and blue ends of the visible spectrum but not the green light which is reflected back. This is why the plant appears to be green.

There are three limiting factors in photosynthesis they are: light intensity, the amount of carbon dioxide, and temperature. These three things affect the rate at which the plant can photosynthesize. We call them limiting factors because if any of these three factors are not at the correct level then photosynthesis will be limited.

We know that plants must have carbon dioxide to photosynthesis and if the carbon dioxide concentration is increased then so will photosynthesis. We also know that temperature is also a limiting factor in photosynthesis, any temperature below 30ºC and photosynthesis will slow down, but anything above 45ºC and the chlorophyll enzymes will be denatured and photosynthesis will slow down completely. However any temperature between 30-45ºC and photosynthesis will speed up.

So in this experiment we will be investigating what effect light intensity has on the rate of photosynthesis.

I predict that as the intensity of the light increases so the rate of photosynthesis will in direct proportion with the light intensity. I predict this because light is a limiting factor in photosynthesis. Photosynthesis cannot occur without light, so at a low light the plant will not be able to absorb enough light and will have to slow down its rate of photosynthesis. But when the light is then increased the plant will absorb as much light as it can. Therefore if the plants absorbing larger amounts of sunlight it will have to increase its rate of photosynthesis to keep up with the amount of light it is absorbing.

Method:

To do this investigation we are going to have to measure the amount at which the plant photosynthesizes, in different light intensities. The best way to measure the amount at which a plant is photosynthesizing is to measure the amount of oxygen the plant is giving out (as we know that oxygen is a by-product of the chemical reaction involved in photosynthesis), if the rate of photosynthesis is increasing then so will the amount of oxygen that the plant is giving out. Unfortunately we do not have the apparatus to measure how much gas a plant is giving off but instead we are going to use elodea, which is a type of pond weed. By submerging the pond weed in water then placing it in different light intensities, for a set amount of time, we can count how many oxygen bubbles the elodea gives off, thus giving us a good idea of how much oxygen is being given off as a by-product of photosynthesis. The more bubbles, the more oxygen the more the plant is photosynthesizing. The less bubbles, the slower the rate of photosynthesis.

Apparatus:

Bench lamp
Ruler

Elodea, pond weed
Test tube
Test tube holder
Timer
Light intensity measuring device
Water

<u>Detailed Method:</u>

1.) Set up the apparatus as shown above.
2.) Place the pond weed in the test tube with 25ml^3 of water.
3.) Place test tube in test tube holder.
4.) Measure the distance from the elodea to the light.
5.) Turn on the lamp.
6.) Measure the light intensity.
7.) Start the timer and count how many bubbles the elodea gives off in 1minute.
8.) Record results and repeat.

<u>Fair test and variables:</u>

To keep this a fair test we will only change one variable, that variable will be the distance between the elodea and the light source. Moving the elodea further away from the light source will give us the different light intensities that we need to do this investigation. Other variables we could have changed include: the colour of the light source as chlorophyll easily absorbs blue and red light but not green light, the CO2 concentration in the air which we know would effect the rate of photosynthesis, water availability as water is needed in photosynthesis, the amount of time that we let the pond weed photosynthesize for and temperature which we know is also a limiting factor.

We will keep the colour of the light source the same by using the same lamp with a normal white light with no coloured filters. We will do the experiment in the lab in with normal concentrations of carbon dioxide. The same amount of water will be used in each experiment and all the experiments will be done at room temperature. We will count the amount of bubbles for exactly one minuet and no longer to keep the test fair. We will only move the lamp 1cm away from the pond weed at a time starting at a distance of 2cm away up to 6cms away. We will do each experiment 3 times and take an average, this will make the test fairer and we should be able to spot anomalies more easily.

Safety:
There are no great safety risks involved in this experiment, so there are no safety precautions needed other than to be careful when using electricity around water.

Trial:
To make sure that are experiment would run smoothly and that we were using the right measurements and amounts we decided to do a trial run of our experiment.

We followed our plan exactly and found that it worked and are measurements and amounts were appropriate for this experiment and there were no major problems with our plan. We will now carry on with our full investigation using the plan specified earlier.

Results:

1st

Distance (cm)	Light intensity (%)	No. of bubbles
2	95	39
3	90	36
4	89	21
5	88	16
6	87	12

2nd

Distance (cm)	Light intensity (%)	No. of bubbles
2	98	42
3	96	39
4	89	20
5	88	14
6	87	13

3rd

Distance (cm)	Light intensity (%)	No. of bubbles
2	98	39
3	90	35
4	89	29
5	88	18
6	87	16

Average

Distance (cm)	Average No. of bubbles
2	40
3	36.7
4	23.3
5	16
6	13.7

Conclusion:
The graph shows a strong negative correlation in relation to distance. So from my results I can see that my prediction was in fact correct, light intensity does effect the rate of photosynthesis, the more intense the light the greater the increase in photosynthesis. There was only one anomaly (distance: 3cm, no. of bubbles: 36.7) and although the result is less than the result for 2cm it is still not low enough to fit the in the line of best fit on the graph. This anomaly could be due to a human counting error or an error in the plan. So relating back to the introduction/prediction as the light intensity increases the production of glucose directly increases to keep up with the amount of light that is being absorbed in the chlorophyll.

Evaluation:
Although I feel are experiments went well and the results were accurate there are a few things that could be changed to make the experiment more precise. The first and probably most important fact is that in this experiment we rely mainly on the fact that all the air bubbles are the same size, which obviously they are not. This then means that are results although not wrong because even with this error it still gives us a good idea of how much oxygen is being given off, are not totally accurate. To be able to correct this error we would need to have special equipment that could measure the amount of gas being given off, which in a school lab we obviously do not have. Also the distance between the lamp and the Elodea is not measured very accurately especially when for the measurement to be totally correct we would have to measure from the filament of the lamp to the Elodea which we could not do in this experiment as the glass of the light bulb was in the way. These distance errors should not make too much difference to my results as they were only a guide to the light intensity and we did also collect the light intensity percentage which is a lot more reliable. Another problem is temperature. Which as I stated earlier is a limiting factor on photosynthesis, so if the temperature of the water the pond weed was in was to increase by a few degrees this could have quite an impact on our results. To eliminate this error in future experiments we should place the pond weed in water of a specified temperature before the experiment starts and keep the water to the agreed temperature for each of the experiments. The temperature would need to be kept constant at all times. The carbon dioxide concentration in the air is also another problem as if it were to increase then so would the rate of photosynthesis thus making the experiment unfair and in accurate. The carbon dioxide concentration may naturally be higher in the lab during one experiment than other, especially if there are more people in the room as more people would equal more carbon dioxide being breathed out thus increasing the concentrate. Once again there is not much we could do to stop this in a school lab but in a bigger science laboratory they would be able to use equipment that would keep the carbon dioxide constant. Human error also comes into play as well, as if the person counting bubbles was not totally concentrating they might miss a bubble or think they saw a bubble when they didn't this could cause serious problems with the accuracy of our results. What's more there is also the problem of when to start the timer, should the timer be started after the first bubble or before the first bubble thus meaning less bubbles were counted. In future experiments this should be specified in the plan and stuck to with each experiment. So although for our small experiment I feel our results and my prediction are justified there are many things that could be changed to make our experiment more reliable and accurate as stated earlier.

To extend our experiment we could try using coloured light to prove that the colour of the light is also a limiting factor, or see whether it is only certain types of light that effect photosynthesis by trying different types of light such as fluorescent or halogen lights. We could also try involving more of the other limiting factors such as temperature or carbon dioxide concentration by linking them into this experiment as well as investigating them as limiting factors on there own. One other way of extending out investigation would be to try using a different method of measuring whether light is a limiting factor in photosynthesis such as measuring how much carbon dioxide the plant is using instead of how much oxygen it is giving out and then comparing the results with the results we gained from this experiment.

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