Investigation to find out how light intensity effects the rate of photosynthesis

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Introduction

Flowering plants, like all living organisms, need a supply of food. They need it as a source of energy in respiration and they need it as raw material for growth and repair. Animals and most micro- organisms get their food in an organic form: they eat products from other organisms (such as fruit and eggs) or, nowadays, the organic substances made in laboratories and factories. Animals and the microorganisms that do this are called consumers.

Due to the flowering plants can make their own organic food from simple inorganic substances and an outside source of energy, they are called producers. Once the producers have made their food they use it in the same way as the consumers do as a source of energy and as raw material for growth and repair

Photosynthesis

The simple inorganic substances from which flowering plants make their food are carbon dioxide (CO_2) and water (H_2O). These contain no energy that a flowering plant can use an outside source of energy is needed to combine them into a compound that the plant can use as food. The source of energy is sunlight; the food compound that is made up the simple sugar, glucose ($C_6H_{12}O_6$), and the waste product that is left photosynthesis, is shown in an equation as:

$$\text{Carbon dioxide} + \text{Water} \longrightarrow \text{Glucose} + \text{Oxygen}$$

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

Light energy is trapped by photosynthesis and converted into chemical energy in compound glucose.

Carbon Dioxide

Carbon dioxide is a gas which is present in air only in small amounts about 0.04% of air is carbon dioxide. But carbon dioxide is continually added to air by respiration of all living organisms and by burning of fuel such as wood, coal, gas, oil and petrol all give off carbon dioxide when they burn. There is no danger that carbon dioxide will run out in fact it is slowly increasing in the air because so much burning takes place. Carbon dioxide dissolves in water, which can release carbon dioxide: flowering living plants living in water therefore also have a supply of carbon dioxide.

Water

Flowering plants that live on land get the water for photosynthesis through their roots from water in the soil. The water travels through the plants in veins called vascular bundles. Plants that live in water get it from their surroundings.

Energy

Light rays are a form of energy they are wave movements traveling at great speed. Those of a certain wavelength, which are seen by our eyes, are light rays. Flowering plants have a green pigment called chlorophyll which can absorb some of these light rays and use their energy to build up the simple sugar, glucose , from carbon dioxide and water. The light energy is trapped as chemical energy in the glucose molecule. Plants can use any source of light rays, but the source that does not run out is sunlight. Artificial light is used in glasshouses when extra light is needed. In water, only the top few meters get sufficient light for plants to use in photosynthesis. Plants that are able to detect a source of light grow towards it, for example, cress.

The growth of plants in relation to the direction of light is called phototropism. Because the stem grows it is said to be positively phototropic. Phototropism is an example of a plant responding, in the direction of its growth, to the stimulus of light. Growth responses in plant s positive phototropism is to the plant: it puts its leaves into the light for photosynthesis.

The products of photosynthesis

If you look at the equation for photosynthesis , there are two products called glucose and oxygen. They cannot accumulate in the mesophyll cells indefinitely.

A the glucose forms, it is usually stored in the chloroplasts as starch. If you test a leaf for glucose during photosynthesis, you are likely to find very little because it is changed to starch so quickly after it is formed. If you test a leaf for starch during photosynthesis, you find quite a lot. But at night, when photosynthesis stops because there is no light, the starch is changed back into sugar and removed from the leaf through the veins either to a growing part of the plant or to a more permanent storage place.

Throughout photosynthesis waste oxygen is given off as a gas, because it is in a high concentration in the cells, it diffuses to the outside of the leaf, where it is in a lower concentration, via the air spaces and open stomata. The formation of oxygen during photosynthesis is of great importance to all living organisms. All living organisms, including plants, carry out respiration, and most of that respiration is aerobic (using oxygen). Photosynthesis is the only way in which oxygen used in respiration is replaced in the air.

The site of photosynthesis

For photosynthesis to occur, carbon dioxide, water and light energy must come together where there is chlorophyll in the flowering plant. Leaves, which are usually broad and flat, are the parts of the plant most suitable for photosynthesis.

- Contain chlorophyll
- Have a broad flat area which is supported by veins and is exposed to the rays of the sun.
- Contain veins (vascular bundles) which supply water
- Are thin, allowing quick diffusion of carbon dioxide to all parts inside the leaf.

The site of photosynthesis is in the cells inside the leaf. The diagram below show a view of the sort of cell that caries out photosynthesis in the leaf. The living parts of the cell, the cytoplasm and nucleus, are surrounded by a non-living cell wall of cellulose: the cell wall keeps the cell in shape. The green pigment chlorophyll is held in small disc-like shapes, made from specialized parts of the cytoplasm, called chloroplasts. The central part of the cell is a vacuole containing cell sap, which is mainly water.

The cytoplasm is surrounded by a cell- surface membrane. A nuclear envelope surrounds the nucleus.

Chlorophyll pigments absorbs the light energy and convert it into food. This is why it is called photosynthesis. So by using the light energy the plant manufactures its food.

Diffusion of gases in leaves

Aim

My aim is to carry out an investigation into photosynthesis.

I want to find out if light intensity has any effect on the rate of photosynthesis. I want to know if the intensity of light is high, then will the rate of photosynthesis will be faster. Further investigation is to find out various light intensities and the rate of photosynthesis by using coloured light filters.

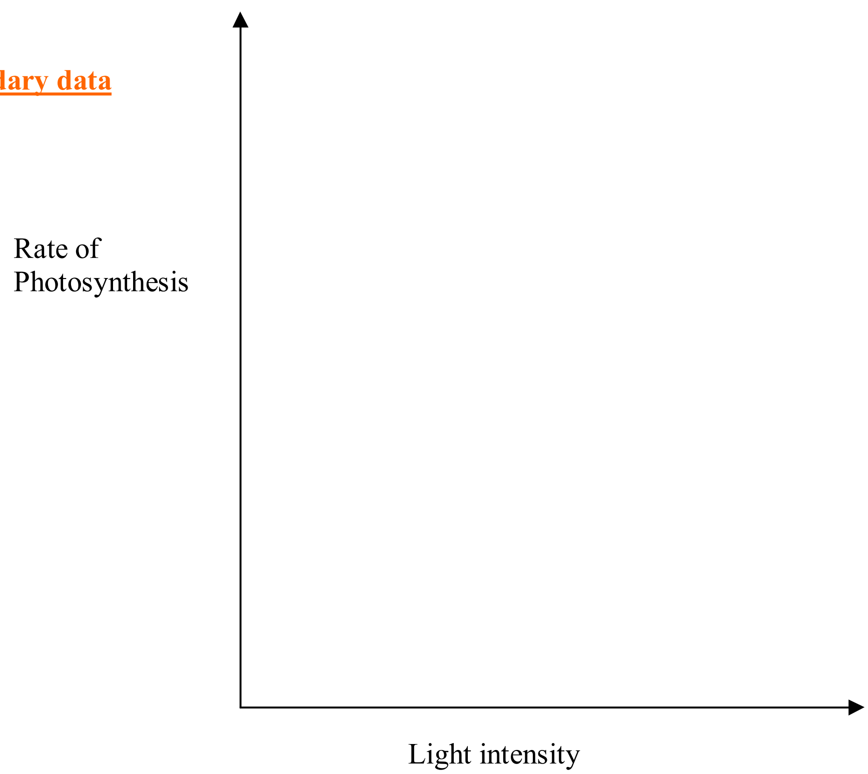
Hypothesis

The effect of light intensity on the rate of photosynthesis

Photosynthesis depends on the amount of light available. Increase in light intensity increases the rate of photosynthesis and less of it decreases its rate. This is what is going to happen in my experiment. When the lamp is closest to the jar, the rate of photosynthesis or the number of bubbles produced will be the most. As the lamp will be moved away from the jar the number of bubbles produced will decrease so will the rate of photosynthesis.

Therefore I predict that as the lamp will be moved away from the jar the number of bubbles will decrease thus decreasing the rate of photosynthesis. Also different filters mean different wavelengths of light. At different wavelengths, the absorption of the light energy also varies; therefore the rate of photosynthesis will also vary. The secondary data of graph (action spectra) demonstrates. The rate of photosynthesis varies with different wavelengths of light

Secondary data



The secondary data above backs-up my prediction because it shows that, as the intensity of light increases, so does the rate of photosynthesis until point x. After point x another factor might be affecting the rate of photosynthesis, which is known as a 'limiting factor'.

Variables

The effect of light intensity on the rate of photosynthesis

Independent Variable

- Oxygen is independent
- The light intensity is independent
- The time is a constant independent

Dependent Variable

- The amount of oxygen produced is dependent on the rate of photosynthesis
- The rate of photosynthesis is dependent on the light intensity

Precautions

Precautions play an important part in every experiment

- Bags and books must be kept away from the apparatus and the place where the practical is set up.
- There should be no smoking in the laboratory
- In both of the practicals, the lamp must not be kept too close to the leaves for a long period of time. This is because chlorophyll is an enzyme and gets denatured by excessive heat.
- The leaves chosen for the practical must not be variegated or yellow. They must be green.

Fair Testing

By applying fair testing to a practical, a candidate can be fair in obtaining his or her results. The fair testing I am going to apply to my practical is: -

- I will set up the apparatus exactly as shown in my method.
- In the effect of light intensity on the rate of photosynthesis experiment, I will use a ruler to measure the distance of the lamp from the jar.
- I will count the number of bubbles produced by marking dots on the paper as the bubbles are produced. Then I will count them to write how many bubbles are produced.
- I will repeat my experiment twice to improve their validity and reliability.

Apparatus

1. Pondweed

2. A beaker of water

3. 10cm3 of sodium hydrocarbonate

4. Funnel
5. Bench Lamp
6. Stop Watch

Method

1. Fill a beaker with tap water and add 5cm3 saturated sodium hydrocarbonate solution.
2. Select a pondweed shoot about 2-4cm long
3. Set up apparatus as shown in diagram
4. Place a bench lamp about 8cm away from the beaker, switch on and start the timer
5. Record the number of bubbles produced in ten minutes.
6. Repeat step 1-5, moving the bench lamp to 20cm away from the beaker.

Diagram for Method

Results

The effect of light intensity on the rate of photosynthesis.

Lamp at 8cm away from the beaker

Time (minutes)	*Number of oxygen bubbles*
1	34
2	56
3	78
4	93
5	108
6	139
7	145
8	158
9	189
10	196

Lamp at 20cm away from the beaker

Time (minutes)	*Number of oxygen bubbles*
1	12
2	19
3	33
4	58
5	65
6	74
7	91
8	95
9	99
10	106

Graph for test 1 and 2

Graph for the rate of photosynthesis

Analysis of Results and Graphs

To work out the gradient I shall use the formula of dy/dx. The meaning of dy is the difference in the y-axis and the meaning of dx is the difference in the x-axis. By using the gradient I shall also be enabled to work out he rate of reaction. The gradient for the experiment when the lamp is 8cm away from the beaker, at point A it is 12.27, at point B it is 22.38. The gradient for the experiment when the light is 20cm away from the beaker, at point A it is 11.74, at point B it is 12.41 and at point C it is 12.22. From the gradient of the two lines I shall be able to draw a graph on the rate of photosynthesis.

From the graph of Rate of Photosynthesis I have noticed that there has been a decrease in the rate of photosynthesis when the beaker was at 20cm from the beaker, besides that the rate of photosynthesis graph looks corrects.

Conclusion

Using my results, I found my hypothesis is correct. The higher the light intensity, the more bubbles were produced. However the diagram in page 7 shows how photosynthesis does change.

This proves my hypothesis is correct, because after a certain point the line stays on the same level. On section A of the graph showing an increase in light intensity, it shows as the light intensity is increasing, the rate of photosynthesis is also increasing. Point X is the optimum temperature. At section B the line is becoming constant. This is because the rate of photosynthesis is slowing down because the temperature has reached its optimum and now increase in temperature has an effect on the rate of photosynthesis.

The bubbles produced are bubbles of oxygen. In the chemical equation for photosynthesis it states glucose and oxygen is produced from carbon dioxide and water.

From my results, I didn't come to a reasonable conclusion. Perhaps there was a limiting factor in the process of photosynthesis. It could be because the light was too far away or the change of surroundings. The temperature of water may not be accurate enough for photosynthesis for photosynthesis to take place, there may not be enough carbon dioxide or even too much. Whatever the reason the main conclusion for normal results is dependent on the light intensity.

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 photosynthesize at a steady rate, even when the distance from the plant to the light source was kept a constant. The second reading at 8 cm was far greater than the first reading at 8 cm. While the number of oxygen bubbles was being recorded, the rate at which the plant was photosynthesizing had increased several times. 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 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. Microorganisms living on the pondweed may have even used some oxygen. 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 pondweed 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. 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. 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. 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 wavelength 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. Wavelength 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.

Errors, Limitations and Improvements

Like all experiments there is always room for improvement and this one is no exception. My main limitation was time. If there had been enough time I could have carried out the same experiments but in various different ways, another problem that occurred with my experiment was that the temperature had been fluctuating whilst the lamp was at 8cm from the beaker. I could have done the experiment more than once but this would have been a waste of time as I felt my present results were good enough. I could have used a couple of different types of pondweed to see if this made a difference to the results. If I was to do this experiment again then this is the method that I would use to improve it.

- Collect a beaker of 100ml. Fill up to 100ml
- Collect a fresh piece of Elodea (Canadian pondweed) about $5cm^3$ long
- Attach the pondweed to two paper clips, so that it is weighed down. Then place the Elodea into the water
- Take the funnel and place it over the Elodea upside down
- Measure 10cm intervals up to 1m away from the lamp
- Start stopwatch when the light is turned on
- Count how many bubbles are produced in 2 minutes
- And repeat the same experiment 3 times.

Hopefully using this method will make a better experiment and produce better primary results, so that secondary data doesn't have to be used. Apart from some problems the experiment went quite well.