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How does light intensity affect Photosynthesis

Introduction

Photosynthesis is a very important process in nature. Photosynthesis is a biochemical reaction used to produce glucose using light energy, water and CO_2 (Carbon Dioxide). A bye product of the reaction, photosynthesis, is Oxygen. It takes place in all green plants, which use the green chlorophyll, held in chloroplasts in the leaves, to trap light. The main site of photosynthesis is the palisade mesophyll cells in the leaf of a plant. It is these cells that contain the green chloroplasts and are very well adapted to do their task. They are near the upper side of the leaf where they can obtain the maximum amount of light, they are packed very closely together and as already mentioned contain green chloroplasts clustered towards the upper side too.

Plants photosynthesise to produce food chemicals that are needed to allow them to grow. The main reaction is to produce oxygen and glucose to be changed into energy during respiration. Glucose is stored in the form of starch which is insoluble and does not affect the osmosis taking pace in the plant. As plants respire both day and night this starch is often used up during the night when photosynthesis cannot take place. The uses of glucose within the plant are for active transpiration, cell division, the production of protein and the production of cellulose. Light energy is used to break down the bonds in water and carbon dioxide a then to make new bonds between atoms to form glucose and oxygen.

In photosynthesis the raw materials are carbon dioxide and water. They react to form the products of the reaction-oxygen and starch (glucose that has been stored). The reactions need energy and this comes from light. The green chloroplasts allow light to be used as energy and therefore both of these things are like helpers in the reaction. Glucose is formed firstly then turned into starch to be stored up for when it is needed.

Although photosynthesis is a complicated process it can be summed up in this equation:

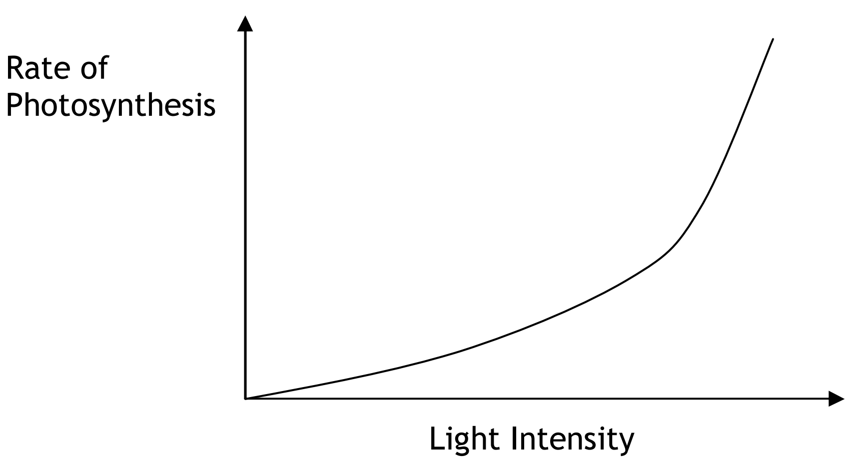
$$\text{Carbon Dioxide} + \text{Water} \xrightarrow{\text{light}} \text{Glucose} + \text{Oxygen}$$

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

It is important to the reaction that certain factors are present when it is occurring. We know that these are carbon dioxide, water, light and chlorophyll. Without these the reaction will not take place at all, but some of them also determine how quickly the reaction takes place. Water, carbon dioxide and light, along with temperature, all have a particular effect on the rate of photosynthesis. In terms of carbon dioxide the levels in the atmosphere do not really alter very much, but if people want to increase the rate of photosynthesis then sometimes carbon dioxide is added into greenhouses. Up to a certain point as temperature goes up so does the rate of reaction. After it reaches a certain point though the enzymes involved in the reaction become denatured and stop working properly. A drop in the amount of water present may cause photosynthesis to occur at only half the normal rate. The reason for this is the stomata are closing.
The final factor which contributes is light. I decided to investigate how this affects the rate of reaction also.

Prediction

I predict that as the light intensity is increased the rate of photosynthesis will also increase. However at a certain point the light will reach a point where the rate will not increase any more. The chloroplasts will no longer be able to absorb any light so the rate will stay at its optimum level or even decrease. At this point light is no longer limiting.
This is a graph of my predicted results, it should look like this.



Law of Limiting Factors

The law of limiting factors states that any process that requires two or more factors will have its rate determined by the slowest or lowest factor.

Limiting factors:

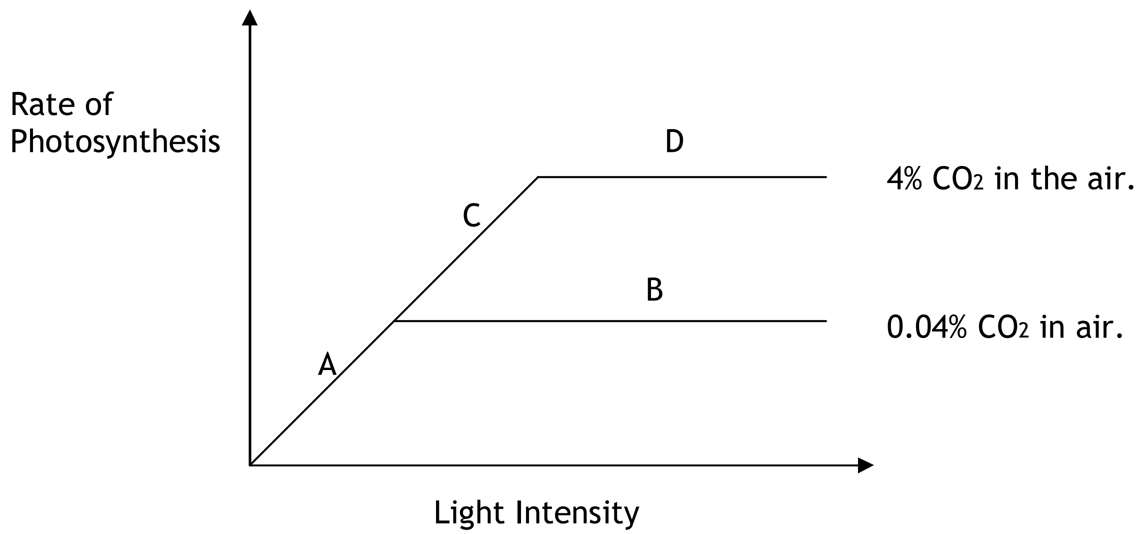
- CO2 concentration.
- Temperature.
- Water.
- Light intensity.
- Chlorophyll.

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 gathered at a reaction center, ATP can be synthesized from ADP. During this reaction, oxygen is produced as a bye-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 gathered to fuel the 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.

↑ Information obtained from web site.

This plant is kept well watered at 25°C and has dark green leaves.



At point A while the light intensity is increasing the rate of photosynthesis is also increasing, because there is increased light energy used to break bonds to make new bonds.

At point B the rate of photosynthesis stays as it is but the light intensity increases as it goes along, the rate of photosynthesis stays the same because it lacks Carbon Dioxide.

At point C light intensity keeps increasing which goes the same for the rate of photosynthesis, this happens due to increase in Carbon Dioxide concentration.

At point D the probable reason for it stopping is because it has a limiting factor, the limiting factor may be chlorophyll, as there may not be enough to absorb the Light given off.

CO_2

After the light intensity reaches a certain level, the rate of photosynthesis does not increase while the light intensity keeps on increasing. I can prove this by looking at the amount of Carbon Dioxide there is in the atmosphere, the atmosphere is made up of only about 0.04% carbon dioxide. This means that when the light is at a very high intensity, the rate of reaction cannot increase because of the lack of Carbon Dioxide that it needs to react with. When the levels of Carbon dioxide were increased the reaction became faster, this shows that there is another limiting (other than carbon dioxide) factor held at point D.

Temperature

Plants use Enzymes to control reactions and to increase the rates of reaction inside the plants, as it does in animals. When the temperature is increased the enzymes starts to move faster and therefore make reactions in the photosynthesis faster. The optimum temperature for the enzymes to work is at roughly about 30-40 degrees, when enzymes are exposed to temperatures higher than this they are denatured and make the enzymes unable to perform at all.

Variables in this experiment:

The independent Variable is *Light intensity.*

The dependant Variable is *the rate of photosynthesis.*

To make sure this experiment is kept fair other variables are kept the same.

Limiting Factors

- Water. x
- Light energy. x
- Carbon Dioxide Concentration. x
- Temperature (room temperature). √
- Chlorophyll. √

My experiments limiting factors will be *Chlorophyll* and *Temperature*.

In my experiment water shall not be a limiting factor as the plant with be submerged in the water, this will not affect the plant in a bad way since the plant I am using is pond weed. Light energy will not be a limiting factor since it is our Independent variable. Carbon Dioxide will not be a limiting factor as I will put sodium bicarbonate into my water this will make a solution, which allows the water to make CO_2 (carbon dioxide).

<u>Apparatus list</u>

- **Beaker.**
- **Flannel.**
- **1 metre ruler.**
- **Elodea – also known as Canadian pond weed.**
- **Pleistocene.**
- **Stopwatch.**
- **Lamp.**
- **Sodium Bicarbonate.**
- **Water.**

Method.

- Set up apparatus.
- Start up the lamp 100 cm away from plant in dark room.
- Switch lamp on.
- Leave it in place for 2 minutes so it can adjust to the different light intensity.
- Count number of bubbles produced by plant in one minute.
- Record Results.
- Move lamp forward 5cm.
- Leave it for 2 minutes for plant to adjust to amount of light energy.
- Count number of bubbles for 1 minute.
- Repeat steps 4, 5, 6 and 7 until lamp is 5cm away from beaker.
- Record 3 sets of results.+ Repeat experiment with blue and red filters.

I started my lamp at 100cm as opposed to 5cm away from the plant because the plant may be getting extra light and store some of the light energy to use for later, this store of light energy may be stored until later in the experiment when it will be used to create more oxygen which will result in more bubbles. So if the lamp is started off at 100cm away from the plant, the plant will not be able to store light as intense as it will get at the next step of the experiment.

Fairness

To keep the experiment fair, a number of precautions were going to be taken, here are the factors that I was to keep the same:

- Temperature
- Water
- Light bulb voltage
- Same plant (as different plants have different surface areas)
- Time for counting bubbles.
- Time for plant to adjust.
- Same person to count bubbles as different people may not be able to count small bubbles.
- Same person timing, as some people may have different reactions as others.

Reliability

For this experiment to be reliable I repeated the experiment thrice. This would help me to check for reliable results and it is also to show an anomalous result.

Results

Lamp Distance (cm)	Amount of Bubbles		
	Set 1	Set 2	Set 3
100	0	0	0
95	1	0	1
90	2	2	0
85	1	2	2
80	3	3	1
75	5	4	5
70	4	4	3
65	6	5	4
60	8	7	7
55	7	9	7
50	2	11	12
45	13	12	14
40	16	6	14
35	15	17	18
30	19	16	19
25	18	18	19
20	9	20	19
15	22	21	24
10	23	24	21
5	20	26	20

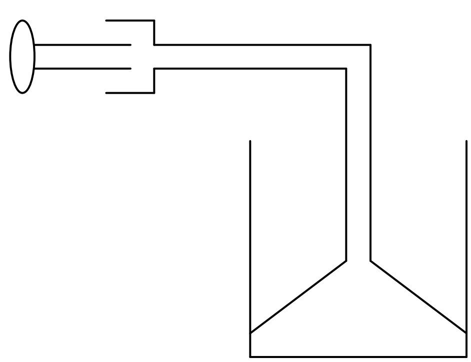
Analysis

From the results that I have gathered I can state that an increase in light intensity certainly does increase the rate of photosynthesis. As was also expected in my prediction, the relationship between light intensity and the rate of photosynthesis was non-linear. From my graphs there is a best-fit curved line. This means that the rate of photosynthesis increases at an very good 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 terms 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.
The greater the distance, the slower the rate of photosynthesis. While the photosynthetic rate increased, the rate at which it increased was decreasing.
Basically as I move the lamp closer to the plant the amount of oxygen bubbles given off are increased.

Evaluation

My anomalous results may have been caused by a human error, or it may have been that the bubbles of oxygen got stuck at a parts of the flannel, these bubbles could have been let out at any time, making it that later on the amount of bubbles would increase. Also at times we stirred the water inside the beaker which caused the stuck bubbles to be let out, this could have caused human error as the person who was counting the bubbles would also count the bubbles which were stuck from previous steps, and were just coming up at that moment. Another point of inaccuracy would be that many of the bubbles were of different sizes and we still counted them, in the early steps there could have been many small bubbles, but in the later steps, there could have been the same amount of slightly larger bubbles.

We could have also used a syringe to calculate how much oxygen was coming form the plant, this would have been better because we would not have been counting the amount of bubbles which may have varied in sizes, but the amount of oxygen, which contains no flaw. Also another advantage of using a syringe would be that we could leave it for a longer period of time, we could also give it more time to climatise, so it could get used to the amount of light being put on it.

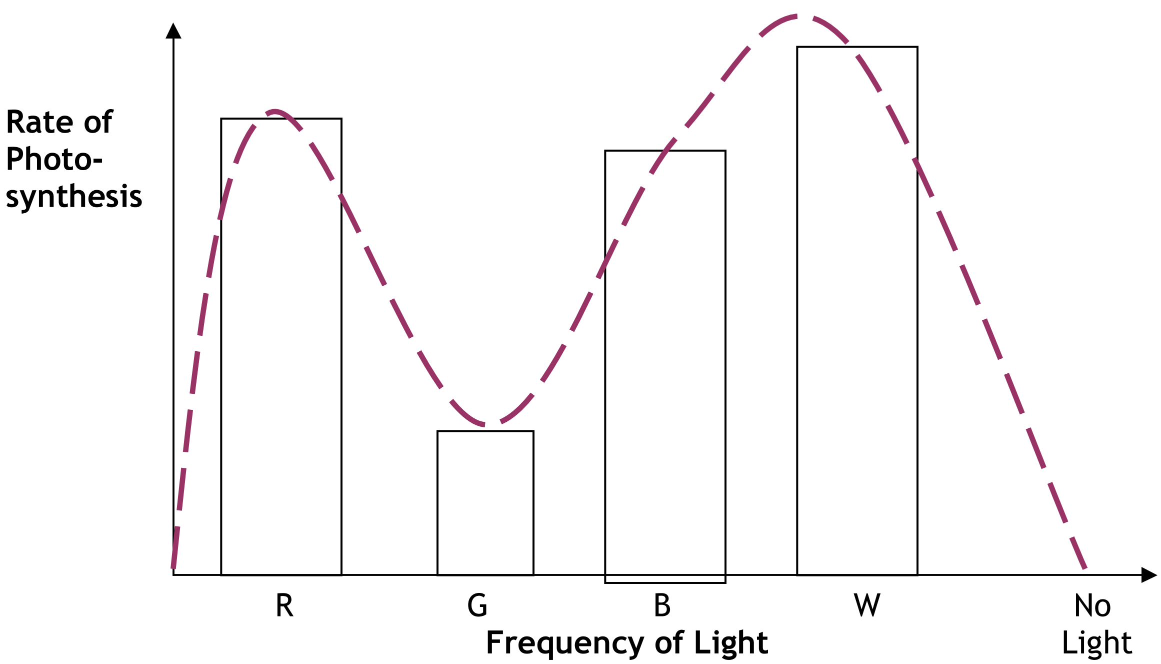


Reliability

I have enough evidence to say that my results given are valid results given that my experiment has been repeated 3 times. My results show me that 3 steps of results are in close arrangement and I would say that they are reliable. To make my results more reliable I could have recorded results for every 1cm as this would have been more reliable because it would have allowed me to make more accurate calculations of bubbles per minute of this experiment.

Extension.

I theorise that there are 3 primary light frequencies for white light (red blue green). I predicted that the chlorophyll absorbs the red and blue light and reflects the green light.



Apparatus

- **Flannel.**
- **1 metre ruler.**
- **Elodea – also known as Canadian pond weed.**
- **Pleistocene.**
- **Stopwatch.**
- **Lamp.**
- **Sodium Bicarbonate.**
- **Water.**
- **Syringe.**

- **Beaker x2.**

- **Different colour filters.**

Method.

- Set up apparatus.
- Start up the lamp 100 cm away from plant in dark room.
- Switch lamp on.
- Leave it in place for 2 minutes so it can adjust to the different light intensity.
- Count number of bubbles produced by plant in one minute.
- Record Results.
- Move lamp forward 5cm.
- Leave it for 2 minutes for plant to adjust to amount of light energy.
- Count number of bubbles for 1 minute.
- Repeat steps 4, 5, 6 and 7 until lamp is 5cm away from beaker.
- Record 3 sets of results and repeat experiment with blue and red filters.