An Investigation to find out how Light Intensity affects Photosynthesis in Pondweed.

The investigation is intended to demonstrate the way in which photosynthesis in pondweed is affected by light intensity. I have read about photosynthesis in [illegible] by B.S. Becket, as well as [illegible] by M.B.V. Roberts, and this is my summery:

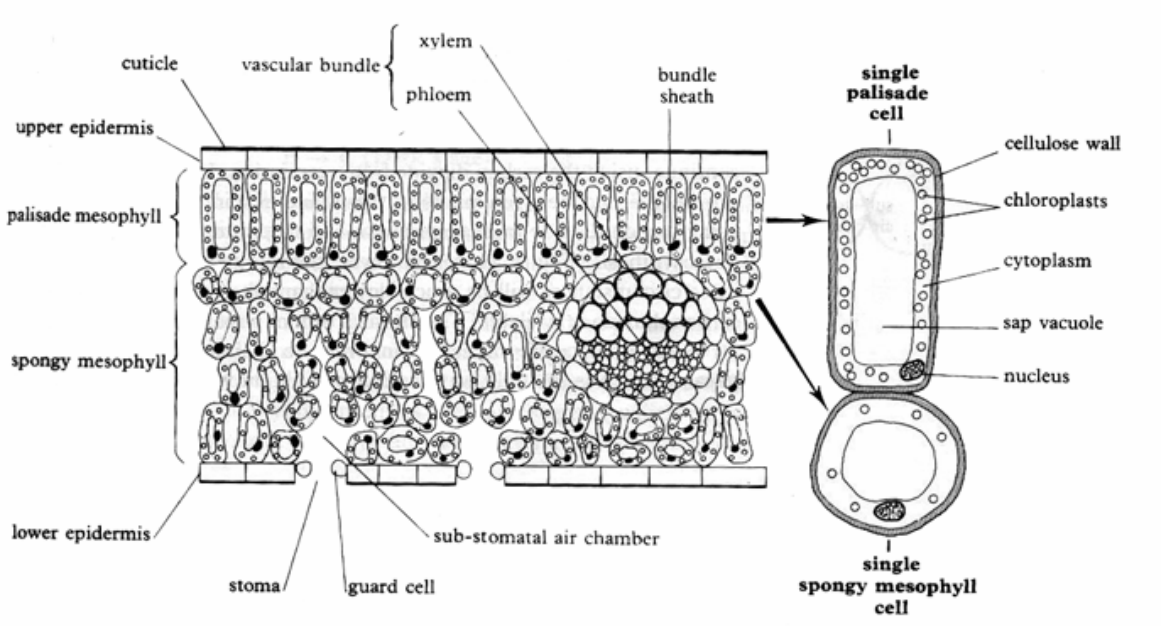
Most plants are neither carnivores nor herbivores, they do not feed on complex organic molecules and can instead synthesis organic compounds from inorganic raw materials, this is called autotrophic Nutrition. There are two different types of autotrophic Nutrition: Chemosynthesis and Photosynthesis. The method used by all green plants is Photosynthesis. Photosynthesis can be summarised by:

$$6CO_2 + 6H_2O \xrightarrow{\text{Light energy, Chlorophyll}} C_6H_{12}O_6 + 6O_2$$

Carbon Dioxide + Water → Glucose + Oxygen

Energy from sunlight is trapped by chlorophyll contained in chloroplasts found mostly in the leaves of plants, and is used to combine carbon dioxide with water. Carbon dioxide is absorbed through pores called stomata which are usually located on the under surface of the leaves, and water is absorbed from the soil by the roots. The main product generated by photosynthesis is monosaccharide sugar (glucose). This can be converted into proteins for growth, broken down into carbon dioxide and water for energy production, or built up into starch for storage. A waste product of oxygen is also released.

The structure of a leaf

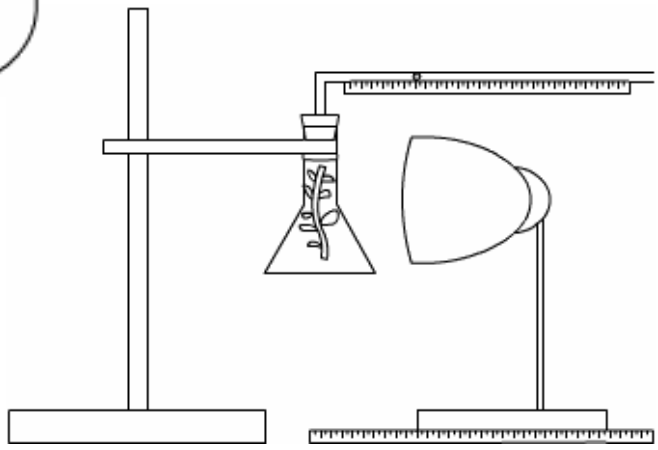


Plan

Oxygen is the only gas released during photosynthesis. Therefore, to find out how light affects photosynthesis in pondweed, I will measure the volume of gas released from some Canadian pondweed (Elodea). I will record the volume of gas releases every minute, for six minutes, before changing the intensity of light the pondweed is exposed to, and repeating the procedure.

The range of equipment available for me to use in school is limited, so this is what I shall be using:

a. Lamp
b. Clamp stand
c. Meter ruler (cm)
d. Bung with a hole in it
e. Water containing Sodium Bicarbonate
f. Bent delivery tube
g. Conical flask
h. Black paper and some sticky tape
i. Scale (mm)
j. Elodea (Canadian Pondweed)
k. Ink bubble
l. Stopwatch



In order to get the ink bubble into the delivery tube I will use the foll owing method:

1. Seal the top end of the delivery tube.
2. Dip the bottom end of the delivery tube into a pool of ink.
3. Seal the bottom end of the delivery tube.
4. Remove the seal from the top end of the delivery tube.
5. Tip the delivery tube up and release seal to position bubble, and then replace seal.
6. Seal the bottom of the delivery tube to the test tube, and then finally remove the seal from the top of the delivery tube.

To discover accurately the affect of light intensity on pondweed (i.e. maintain a fair experiment), I shall have to supply sufficient amounts of four of the five factors necessary for photosynthesis to take place, these are carbon dioxide, water, chlorophyll, and heat. This is so that the fifth factor, light, is the only factor limiting any photosynthesis that takes place. In addition, the levels of carbon dioxide, water,

chlorophyll, and heat need to be kept at a constant. This is so that light intensity is the only variable of which the affect is being measured. Since the investigation is intended to demonstrate the way in which light intensity affects photosynthesis in pondweed, I will obviously have to vary the light intensity. If I varied both the light intensity and levels of carbon dioxide, for instance, and kept the other three factors at a constant, my results would show the effect of both light intensity and carbon dioxide on the rate of photosynthesis in pondweed. It is for this reason that light intensity will have to be the only factor I vary. I know that the natural amounts of carbon dioxide, water, chlorophyll, and heat are of a sufficient quantity, since pondweed survives in the wild. For this reason I shall not alter the amount of heat subjected to the pondweed. Ideally, I would sustain a constant temperature but due to limited equipment, this is not possible. In addition, I shall not alter the amount of chlorophyll present in the pondweed, or it's size and surface area. I shall maintain this by simply using the same piece of pondweed for each set of results. This may however cause the pondweed to slightly loose it's efficiency at photosynthesis. Though this inaccuracy would be lesser than that caused by using different pieces of pondweed for each set of results, since it would be almost impossible to obtain several pieces of pondweed that were identically sized, had the same surface area, and contained an equal amount of chlorophyll. Ideally I would prefer sustain the pondweed's natural supply of water and carbon dioxide, but by removing the pondweed from the pond and placing it in a test tube, I have already altered the amount of water and carbon dioxide that the pondweed has to use. To compensate for this I shall add Sodium Bicarbonate to the conical flask full of pond water I will provide. Since both water and carbon dioxide are used in photosynthesis, the water will need to be replaced for each set of readings ensuring there will be equal amounts of water and carbon dioxide each time. The water will be replaced with the same volume of water, which comes from the same source, containing the same amount of sodium bicarbonate.

I will record the location on the scale, of the beginning of the ink bubble every 30 seconds for 5 minutes. Then using the formula $v=\pi r^2 l$ (where v is volume, r is radius and l is length), I will be able to work out the volume of gas released from the pondweed every 30 seconds over the 5 minutes. I will repeat this at least three times, replacing the water each time, and moving the lamp 25cm away from it's previous position, when it's first position is at 0cm.

Since plants respire, the waste products of carbon dioxide and water will also be released:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

Therefore, I shall carry out a control experiment where the light intensity is nil (the lamp will be turned off and the test tube wrapped in black paper, stopping any light from getting to the pondweed). This will cause any photosynthesis to cease and provide a set of results I can use for comparison with my other results. With these results I will then be able to work out the volume of gas released during respiration alone, enabling me to work out the approximate volume of gas released during photosynthesis with the varied intensities of light.

Prediction

I predict that the rate of photosynthesis will increase as the light intensity increases. Since the supply of the other four factors necessary for photosynthesis is limited, if the light intensity increases too much the rate of photosynthesis will stop increasing. In addition, because the pondweed is in a sealed container, if the speed of photosynthesis exceeds the speed of respiration, the supply of carbon dioxide and water will not be renewed in tin, and so the rate of photosynthesis will eventually slow down to the rate of respiration. In the long term, this will stop the pondweed photosynthesising enough and will eventually cause it to die. Also, since there will only be the minerals that were present in the water in the test tube, the pondweed's supply of sulphates, phosphates, and nitrates will soon run out. These minerals are not strictly necessary for

photosynthesis, but the pondweed cannot survive without them, and if the pondweed is dead, it cannot photosynthesise.

When the light intensity is nil, I predict a small amount of gas will be released as a result of respiration.

A Predicted graph to show how Light Intensity affects Photosynthesis in Pondweed

A Predicted graph to show how no light affects Photosynthesis in Pondweed

Trial Experiment

	15cm	
Time	**Reading on scale (cm) (to 1dp)**	**Volume (ml) of Gas released during past 30 seconds (to 0dp)**
0:00	9.7	
0:30	9.4	-5
1:00	9.2	-3
1:30	9.0	-3
2:00	8.9	-2
2:30	8.9	0
3:00	9.0	2
3:30	9.2	3
4:00	9.5	4
4:30	9.8	5
5:00	10.1	5
5:30	10.3	4
6:00	10.6	5
Average volume (ml) of gas released every 30 seconds (0dp)	**1**	

My trial experiment revealed several problems with my experiment:

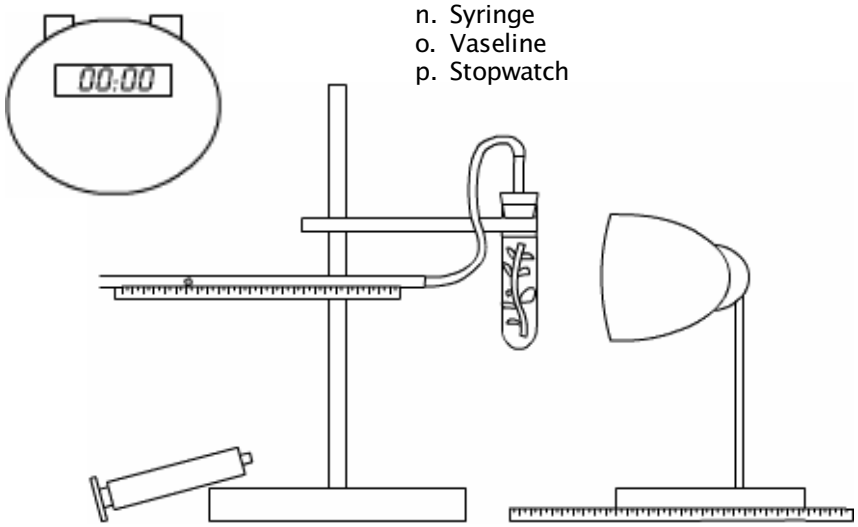
Firstly, for the first two minutes, the volume of the matter contained in the apparatus decreased, as if gas was being used up rather than produced. This was actually because I had placed the lamp next to the test tube while I had set the equipment up, and then had moved it away to a distance of approximately 15cm. The light was considerably hot and had heated up the test tube and it's contents. Therefore, when I moved the lamp away from the test tube, the contents of the equipment compressed as they cooled down, causing the ink bubble to register a decrease of volume. To compensate for this I will leave five minutes before taking any readings, leaving enough time for the contents of the equipment (i.e. the water, pondweed, and the air) to expand or decrease, to the present temperature.

Secondly, my equipment proved to include several flaws:
- The normal delivery tube proved to be too wide to sustain the ink bubble, so I replaced it with a 1mm wide equivalent.
- Equipment was limited, and there was not a bent 1mm wide delivery tube, so I replaced the bent delivery tube with two straight delivery tubes and a rubber pipe.
- I found it very hard to position the bubble. In the end, I found a syringe to be useful for the initial positioning.
- The seal between the delivery tube and the rubber pipe was not totally air tight, so I added some Vaseline to maximise the seal.

Now Vaseline has been added to the seals between the delivery tubes and the rubber pipe, the pipe could easily be moved up and down the tube, which moved the ink bubble up and down the scale, making it much easier to position the ink bubble.

This is my new equipment set-up:

a. Lamp
b. Clamp stand
c. Meter ruler (cm)
d. Bung with a hole in it
e. Water containing Sodium Bicarbonate
f. Scaled capillary tube
g. Delivery tube (short)
h. Rubber pipe
i. Test tube
j. Black paper and some sticky tape
k. Scale (mm)
l. Elodea (Canadian Pondweed)
m. Ink bubble
n. Syringe
o. Vaseline
p. Stopwatch



Analysis

	0cm		25cm		50cm		Control (no light)	
Time	Reading on scale (cm) (to 1dp)	Gas released during past 30 seconds (to	Reading on scale (cm) (to 1dp)	Gas released during past 30 seconds (to	Reading on scale (cm) (to 1dp)	Gas released during past 30 seconds (to	Reading on scale (cm) (to 1dp)	Gas released during past 30 seconds (to
5:00	7.6		4.4		3.7		1.3	
5:30	7.8	3	4.4	0	3.7	0	1.3	0
6:00	8.1	5	4.5	2	3.7	0	1.3	0
6:30	8.4	5	4.6	2	3.7	0	1.3	0
7:00	8.6	3	4.7	2	3.8	2	1.3	0
7:30	8.8	3	4.8	2	3.8	0	1.3	0
8:00	9.0	3	5.0	3	3.8	0	1.3	0
8:30	9.3	5	5.1	2	3.9	2	1.3	0
9:00	9.5	3	4.8	-5	4.0	2	1.3	0
9:30	9.8	5	4.9	2	4.0	0	1.3	0
10:00	10.0	3	5.1	3	4.1	2	1.3	0
Average volume of gas released every 30 seconds (excluding any anomalous results).	**4**		**2**		**1**		**0**	

My results show, when the lamp was placed 0cm from the pondweed, the pondweed produced approximately 4mm³ of gas every 30 seconds. When the lamp was placed 25cm from the pondweed, the pondweed produced approximately 2ml of gas every 30 seconds. When the lamp was placed 50cm from the pondweed, the pondweed produced approximately 1ml every 30 seconds. When the lamp was switched off and the test tube covered in black paper, the pondweed produced approximately 0ml every 30 seconds.

This proves that light intensity does affect photosynthesis in pondweed, and that as I predicted, as the light intensity increases, the rate of photosynthesis increases. In fact, the word photosynthesis suggests this: photo means light, and synthesis refers to the assembly of organic compounds. Though light does affect the rate of photosynthesis, the overall process takes place in two stages, and only the first is light dependant. The second can take place with, or with out light. In the first stage, the light reaction, water is split into hydrogen and oxygen, and ATP is produced. This is where the oxygen is released as a waste gas. The ATP is used in the synthesis of carbohydrates in the second stage, the light independent reactions.

Though contrary to my prediction, I recorded no gas to have been produced when the pondweed is subjected to no light at all. This could be a result of one of three possibilities:

1. No gas was produced by respiration.
2. An insubstantial amount of gas was produced by respiration and so it did not show up on my scale.
3. The equipment I used was faulty, and so the gas was escaping.

Since my experiment only lasted for 10 minutes, the other factors necessary for photosynthesis did not limit the rate of photosynthesis in the pondweed.

Graphs to show how Light intensity affects Photosynthesis in pondweed.

Graph to show how Light Intensity affects Photosynthesis in Pondweed

Evaluation

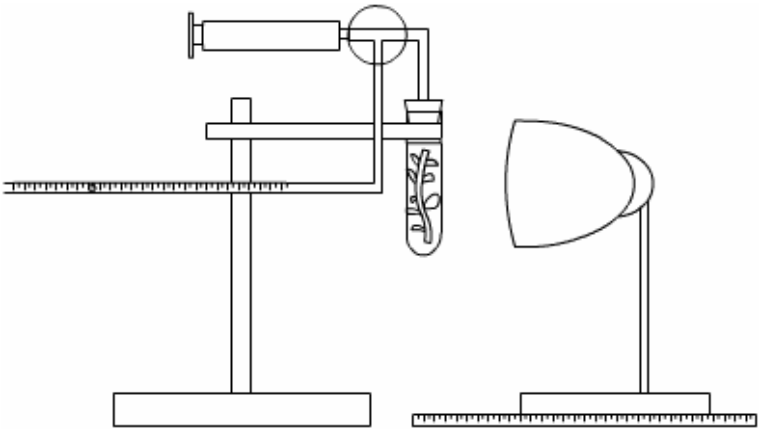
My experiment did prove that as light intensity increases, the rate of photosynthesis increases, though it is not completely reliable. My data contained at least one anomalous result: on the ninth minute when the lamp was placed 25cm away from the pondweed, I recorded that the volume of the matter inside the equipment decreased by 5ml. Unreliable anomalous data such as this could have been recorded due to errors in several main areas:

- The equipment I used may have been faulty and/or inaccurate:
  - It is unlikely that the seals around the delivery tubes were totally air tight, and so it is probable that some gas leaked causing the apparatus to record a lesser increase in volume.
  - As previously stated the lamp gave of a considerable amount of heat, and so when the lamp is close enough to the test tube, it caused the temperature inside to rise. The atoms in the water gain energy making them spread out, increasing their volume. Temperature is one of the four factors I stated I had to keep at a constant, but by using this lamp, and not controlling the rise in temperature, I failed to do so. This means that my results, to a certain extent, show both the effect of Light intensity and temperature on photosynthesis in pondweed.
  - As well as not controlling the temperature, I could not totally control the intensity of light, since I was unable to carry out the experiment in a totally dark room, or a room with a sustained level of light.
  - The scale I used may not have been precise enough.
- The equipment I used may have been contaminated:
  - It is probable that the equipment, in particular the water contained in the test tube, was contaminated with other organisms that would have released gas during respiration.
  - It is possible the equipment contained undesired substances which also could have affected photosynthesis in the pondweed.
- I used the same piece of pondweed for every set of results, meaning the pondweed's ability to photosynthesis may have improved or deteriorated as time went on.
- Human error may have lead to inaccuracies in recording data, either by reading the scale wrong or bad time keeping.

To account for these possible mistakes I should really repeat the experiment a many times and work out an overall average. This would ensure the data is reliable and not a fluke.

In addition, I could use the following equipment to decrease the chance of any fault in my equipment:

a. Fluorescent Lamp
b. Clamp stand
c. Meter ruler (cm)
d. Bung with a hole in it
e. Water containing Sodium Bicarbonate
f. Scaled capillary tube
g. 3 way tap
h. Test tube
i. Elodea (Canadian Pondweed)
j. Ink bubble
k. Syringe
l. Stopwatch



Ideally, the experiment would be carried out in the dark, with no light pollution at all so that I would have total control of the light intensity. The temperature of the lab would be controlled and constant so that my results would not show how temperature as well as light intensity affects photosynthesis in pondweed. In addition, a fluorescent lamp would be used. This is for two reasons, firstly, fluorescent lamps are incredibly more efficient than normal lumen incandescent lamps, meaning they give off less heat. This also would ensure that my investigation only records the effect of light intensity on pondweed and not temperature. Secondly, the light emitted from lumen incandescent lamps is not white light, it is made up of mostly red light, with some green light, and even less blue light. Since the objective of this investigation is to show how light intensity and not colour affects photosynthesis in pondweed, and plant life has evolved over millions of years to photosynthesise using sunlight, a lamp that emits light of daylight quality would be much more adequate. Also, a three way tap combined with a syringe would enable me to reset the ink bubble to 0 for each set of readings, along with the 1mm delivery tube with scale, this would decrease the chance of human error when reading the scale.