BACKGROUND INFORMATION

Equation for Photosynthesis:

Carbon Dioxide + Water $\Longrightarrow$ Glucose + Oxygen

$$CO_2 + H_2O \Longrightarrow C_6H_{12}O_6 + 6O_2\uparrow_{GAS}$$

Photosynthesis is the biochemical process in green plants, which enables them to make their own food. Chlorophyll is the substance that absorbs sunlight; this makes solar energy, which is used to combine water and carbon dioxide forming sugars and starch. Oxygen is released as an unwanted bioproduct.

Some factors that effect photosynthesis are:

Temperature- as the temperature increases the rate of photosynthesis also increases. This is because enzymes, which control many of the stages of the process of photosynthesis, are temperature sensitive and the higher the temperature the more active they become. This is true up to about 38^0C, however if the temperature gets to about 40^0C the rate of photosynthesis decreases. This is because the enzymes denature - All enzymes are proteins. At high temperatures the protein breaks down. The active site has changed so that the substrate no longer fits.

Plant- Different species of plant have different photosynthesis rates due to the different leaf structures of the plant. Even the same species of plant may have different rates because 1 plant may have more chlorophyll in the leaves to absorb light, therefore making the process faster. The size of a plant is also important as this may affect the amount of surface area for gas exchange.

Light Intensity and Chlorophyll Concentration - the rate of photosynthesis increases with an increase in the intensity and quality of light. The longer the exposure to light the more glucose produced. This is because chlorophyll absorbs the light, and then the solar energy is converted into the chemical bond energy in the sugar. The chlorop hyll

absorbs energy from blue and red light, but reflect green. The molecules 'excited' by the absorbed light transfer electrons to energy-carrier substances in the cell, thus providing energy for making carbohydrates. Therefore, the more light and chlorophyll the more effective and quicker the process.

Water content and Carbon dioxide- the whole metabolism of a plant is dependent on water. Although only about 1% of water absorbed is used in photosynthesis. In a drought the rate of photosynthesis tends to decrease. This is because when a plant lacks water their stomata close to prevent further water loss. This means the stomata cell doesn't allow Carbon Dioxide to diffuse into the leaf and so the plant lacks Carbon Dioxide for the photosynthesis reaction, and so this slows the process down.

Mineral content of soil- if there is a shortage of nitrogen and magnesium (these activate enzymes and make chlorophyll) there is a shortage of chlorophyll. As explained earlier on this will effect the rate of photosynthesis.

Light, Carbon Dioxide, temperature, chlorophyll, water content and mineral content are all limiting factors. This means even when there is a surplus of the other variables, the rate of photosynthesis will be limited by the factor missing or there is not a sufficient amount of. Until there is an optimal amount of the limiting factor to increase the rate of photosynthesis the rate of photosynthesis can no longer increase.

I have done a pilot study to investigate some of the factors that might need changing, or could go wrong. From this study I discovered it is probably best if I set a certain amount of time for the plant at each different temperature, this is so each temperature has an equal amount of time, making the experiment fairer. Some of the problems I discovered was that the plant didn't seem to be producing any oxygen bubbles, therefore not photosynthesising. To overcome this problem I will add Sodium Hydrogen Carbonate, this is so I am certain Carbon Dioxide is not the limiting factor, as Sodium Hydrogen Carbonate will produce excess Carbon Dioxide when added to the water.

HYPOTHESIS

I predict that as the temperature increases, the rate of photosynthesis will also increase, meaning more bubbles will be produced (this is because oxygen will be released as a waste product of photosynthesis, and so the more bubbles produced the faster the rate of photosynthesis is going).

However, at a certain point, about 40°C, the rate of photosynthesis will decrease. This is because enzymes, which control many of the stages of the process of photosynthesis, are temperature sensitive and the higher the temperature the more reactive the enzymes will become, therefore increasing the rate of photosynthesis. The reason I believe that at about 40°C the rate of photosynthesis will decrease is that the enzymes will denature around this heat- the substrate will no longer fit the active site. As I think photosynthesis is an enzyme controlled reaction it will follow the trend Q10=2. This means for every 10°C rise in the temperature the amount of bubbles should double. (This means the rate of the reaction has doubled) Although at a certain point, about 40 °C this will be untrue, as the enzymes have denatured and so the rate of photosynthesis will decrease.

APPARATUS

Meter Rule- To measure the distance of the plant from the light. This is so they are kept at the same distance throughout the experiment, making it a fair experiment, as we are not changing more than 1 variable.
Elodea- Species of pondweed we will be using. This photosynthesises at a regular rate.
Boiling Tube- Place some water in this, and then place pondweed in it. So the area is more condensed and oxygen bubbles easier to count.
Beaker- Use this to make a water bath to place pondweed in boiling tube in. This will ensure pondweed is kept at constant temperature.
Thermometer- To measure temperature of water bath.
Tungsten Lamp- To ensure pondweed gets the whole spectrum of colours, and so light is not one of the limiting factors.
Stopwatch- To measure the time the pondweed is in water bath at each certain temperature for. So it is a fair experiment as pondweed gets the same time in each different temperature water bath.
Sodium Hydrogen Carbonate- Produces excess Carbon Dioxide when reacting with water. This will ensure Carbon Dioxide is not a limiting factor.
Kettle and ice- These are both methods by which it is possible to vary the temperature of the water easily.

METHOD

1. Set up the apparatus. Have the Tungsten lamp 10cm away from the plant in it's water bath- measure this with meter rule. Place the Elodea in a boiling tube with water, and then place the boiling tube in a water bath.
2. Make the water bath around plant 10°C- do this using the ice and measure it with thermometer.
3. Place Sodium Hydrogen Carbonate in boiling tube with Elodea and water.
4. Set timer for 4 minutes and record quantity of oxygen bubbles every minute for 4 minutes.
5. Make sure the water stays at a constant temperature.
6. Turn off the lamp after 4 minutes, and then increase temperature of water by 5°C. Repeat steps 2-6 (although do not add any more sodium hydrogen carbonate) going up by 5 °C in temperature every time until results are recorded up to 50°C.

RESULTS

CONCLUSION

Comparing my two graphs I have found that they both follow the same pattern. This means that photosynthesis is an enzyme-controlled reaction. The second graph has supported my hypothesis that as the temperature increases the rate of the reaction of photosynthesis will also increase. This is because the enzymes, which control many of the stages of the reaction, are temperature sensitive and so become more active the higher the temperature, increasing the rate of photosynthesis and therefore the number of bubble's produced. However the two graphs trend lines are different gradients, the second graph is not as steep as the 1st. This could be because as the temperature gets to a certain point (about 45 °C) the enzymes denature, therefore slowing the rate of the reaction down and decreasing how many bubbles are produced.

My Raw Data results also support my hypothesis, however when looking at the means of the different temperatures it is quite varied and doesn't seem to follow a set trend. These however when drawn on a graph becomes much clearer and the anomalous results become more obvious. In general the longer the plant was in each certain temperature the more bubbles produced in that minute, however at certain points my results do not follow this pattern. This could of been due to that fact the enzymes were denaturing at the higher temperatures, and so the longer they spent in these higher temperatures the more enzymes were denatured, therefore reducing the rate of the reaction and the amount of oxygen bubbles produced.

EVALUATION

Several thing went wrong in my experiment, at the very beginning the Pondweed wasn't photosynthesising and so was producing no bubbles, this meant we had to give the plant 4 minutes at each temperature instead of 3 minutes. That meant that we had to be quick to obtain all the results we needed and were pushed for time, therefore some of our measurings and accuracy could be slightly off. The bubbles were very hard to count and sometimes it was hard to tell whether the bubbles were coming from the Sodium Hydrogen Carbonate or the plant, therefore we could have missed or counted extra oxygen bubbles.

We had quite a few anomalous results; this could be because of various reasons, the problems I mentioned above could have affected our accuracy meaning the anomalous results were a misjudgement in the readings. It could also have been due to the fact we varied our temperature and did 50°C before we did 10°C, meaning we had denatured all of the enzymes and killed the plant, so it couldn't photosynthesise when we reached 10°C. Some pieces of the Elodea worked better than others, this could be due to more chlorophyll or more surface area for more effective photosynthesis and ours could have been not very effective. Also it could have been due to the fact the temperature of the water the Elodea came out of was very cold. So when we placed it in our water bath it took a while to be affected by the warmer temperature and activate the enzymes that control many of the stages of photosynthesis. This meant fewer bubbles were produced at the beginning of the experiment as the plant was only just activating enzymes.

Improvements we could make could be that we follow the pattern that we start from the lowest temperature and work up. This is instead of starting at a temperature in the middle, working our way up, then working our way right down to the lowest temperature, because we could have killed the Elodea or affected/ denatured the enzymes so it's photosynthesis rate was decreased. A more accurate way of measuring the amount of oxygen produced was to measure it using volume. We would place a funnel on top of the beaker with the Elodea in upside down and place a measuring cylinder filled with water on top of the funnel. This would mean that as more oxygen was produced the further down the water would move the cylinder enabling us to measure volume. However the disadvantage of this is it might not change in a noticeable way all the time and would take a lot of time to displace any water. We should have placed the Elodea in some water that was a similar temperature to the temperature we were going to start the experiment off at. This would mean the Elodea was not going to take a very long time to warm up when we started the experiment and could start photosynthesising quite quickly, solving our time problem.

Further investigations we could do might be to measure how temperature affects certain factors needed in photosynthesis. For example we could measure how temperature affects the amount of Carbon Dioxide in the air, as if it is affected at certain temperatures it might become a limiting factor during photosynthesis.