PLANT PHOTOSYNTHESIS

LAB REPORT

Name

Date

Course Name

Exercise 1: Carbon, Light, and Photosynthesis

Introduction

Plants form an important part of the food chain due to their ability to perform photosynthesis, wherein they capture energy from the sun and use it to synthesize glucose. They also form a fundamental part of the carbon cycle as they use carbon dioxide from the air to make carbohydrates. The chemical equation for photosynthesis is given below:

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

As the byproduct of photosynthesis is oxygen, plants are responsible for maintaining an oxygen-rich atmosphere on earth.

Photosynthesis takes place in two stages – the first stage is the Light Reaction which, as the name suggests, takes place in the presence of light and the second stage is the Dark Reaction, which takes place in the absence of light. In the light reaction, sunlight is used to generate the energy molecules, Adenosine Triphosphate (ATP) and Nicotinamide Adenine Dinucleotide Phosphate (NADP). In the dark reaction or Calvin Cycle, the plants use carbon dioxide to eventually synthesize glucose molecules.

In this experiment, it is demonstrated that in the presence of light, carbon dioxide, and water, leaf tissues perform photosynthesis which is observed by the presence of gas bubbles on the leaf surfaces. Two types of controls are used in this experiment to demonstrate that both light and carbon dioxide are essential for photosynthesis. One experimental setup is placed under a light source and the other experimental setup is placed in a dark cabinet to prove the significance of light for photosynthesis. An additional control is used wherein the leaves are either suspended in distilled water or in a sodium bicarbonate solution which serves as a source of dissolved carbon dioxide.

Materials

- Baking soda
- Distilled water
- Desk lamp with a 100W incandescent light bulb
- Liquid dish soap
- 10 fresh spinach leaves
- Paper towels
- Ruler
- Dark cabinet (empty shoe box)

- Tap water
- Stopwatch
- Digital scale
- 50 ml graduated cylinder
- 2 pipettes
- 8 plastic cups – 9 oz
- Single-hole paper punch
- 10 ml syringe

Methods

1. A paper towel was moistened with distilled water.
2. Using a single-hole paper punch, 40 uniform discs were cut on the spinach leaves. Care was taken to ensure that no major leaf veins were cut on the leaves as these are for vascular transport and contain fewer chloroplasts.
3. The leaf discs were immediately placed on the moistened paper towel.
4. Another paper towel was moistened with distilled water and placed over the leaves. The entire setup was set aside.
5. Two plastic cups were taken and one was labelled ‘Bicarbonate Solution’ and the other was labelled ‘Distilled Water Solution’ using a permanent marker.
6. Using the digital scale, 0.4 g sodium bicarbonate or baking soda was weighed and added to the cup labelled ‘Bicarbonate Solution’.
7. With the help of the graduated cylinder, 200 ml of distilled water was measured and added to the baking soda powder in the plastic cup. The contents were mixed well until the powder was completely dissolved in the distilled water.
8. Using a pipette, 2 drops of liquid dish soap was added to the bicarbonate solution and gently mixed with the pipette stem. The pipette was discarded.
9. Using the graduated cylinder, 200 ml of distilled water was measured and added to the cup labelled ‘Distilled Water Solution’.
10. Using a fresh pipette, 2 drops of liquid dish soap was added to the distilled water and gently mixed with the pipette stem.
11. Four additional plastic cups were taken and labelled as follows – ‘Distilled Water, Light’, ‘Distilled Water, Dark’, ‘Sodium Bicarbonate, Light’, and ‘Sodium Bicarbonate, Dark’.
12. Using the graduated cylinder, 75 ml of Distilled Water Solution was measured and added to each cup labelled ‘Distilled Water, Light’ and ‘Distilled Water, Dark’. In each case, the solution was poured in at an angle to minimize the formation of bubbles. These two solutions will serve as controls for the experiment.

13. Similarly, using the graduated cylinder, 75 ml of Sodium Bicarbonate Solution was added to each of the two cups labelled ‘Sodium Bicarbonate, Light’ and ‘Sodium Bicarbonate, Dark’. In each case, the solution was poured in at an angle to minimize the formation of bubbles.
14. The 10-ml syringe was taken and the plunger was removed. Twenty spinach leaf discs were placed in the syringe barrel. The plunger was pushed in the syringe until a small amount of air was left in the syringe with the leaf discs.
15. Slowly, 3 ml of the Distilled Water Solution was drawn into the syringe.
16. The syringe was swirled to ensure that all the leaf discs were uniformly suspended in the Distilled Water Solution. The syringe was gently tapped to make all the air bubbles come to the top of the syringe.
17. The syringe was held with the nozzle facing upward and the plunger was pushed upward to expel air completely from the syringe.
18. The nozzle of the syringe was covered with a finger and the plunger was pulled downward to create a vacuum within the barrel of the syringe.
19. Holding this position, the syringe was gently swirled to ensure that the leaf discs are mixed with the solution.
20. While keeping the finger on the nozzle, the tension on the plunger was slowly released to release the vacuum within the syringe. This allows the solution to enter the internal spaces of the leaf discs.
21. Steps 18 to 20 were repeated until each leaf disc had sunk to the bottom of the syringe barrel.
22. A paper towel was taken and folded in half. The entire contents of the syringe were poured onto the paper towel.
23. Of these leaf discs, 10 were transferred to the cup labelled ‘Distilled Water, Light’ and the remaining 10 were transferred to the cup labelled ‘Distilled Water, Dark’. The leaf discs sank to the bottom of the cups.
24. Both the cups containing the leaf discs were placed inside a dark cabinet.
25. The paper towel was discarded, and the syringe and plunger were rinsed well with distilled water.
26. Steps 12 to 23 were repeated using the Sodium Bicarbonate Solution instead of the Distilled Water Solution. The cups labelled ‘Sodium Bicarbonate, Light’ and ‘Sodium Bicarbonate, Dark’ along with the leaf discs were placed inside the dark cabinet.
27. While all the cups were in the dark cabinet, the number of floating leaf discs in each cup was counted and recorded.
28. A desk lamp was set up on the work surface and the cups labelled ‘Distilled Water, Light’ and ‘Sodium Bicarbonate, Light’ were placed under the lamp. The other two cups

labelled 'Distilled Water, Dark' and 'Sodium Bicarbonate, Dark' were left in the dark cabinet.

29. The timer was started as soon as the lamp was switched on and the number of floating leaf discs in each of the 4 cups was counted after every 2 minutes. The results were recorded in a table. Occassionally during the experiment, the cups were swirled to ensure that no leaf discs were sticking to each other or to the bottom of the cup.
30. After 20 minutes of beginning the experiment, the two cups in the dark cabinet were removed and set aside for use in the subsequent experiment.
31. The two cups that were placed under the lamp were transferred to the dark cabinet and the timer was immediately started. After every two minutes, the number of floating leaf discs were counted and recorded in a table until the completion of 20 minutes.
32. At the end of 20 minutes, the cups were removed from the dark cabinet and set aside for use in the subsequent experiment.
33. Using the data recorded in the table, a graph was plotted with time on the x-axis and number of floating discs on the y-axis.

Results

Four different experimental setups were prepared in which two solutions of distilled water and sodium bicarbonate were used. One setup each of distilled water and sodium bicarbonate were placed in light and one setup each of distilled water and sodium bicarbonate were placed in the dark. Spinach leaf discs were used to observe photosynthesis under different experimental conditions.

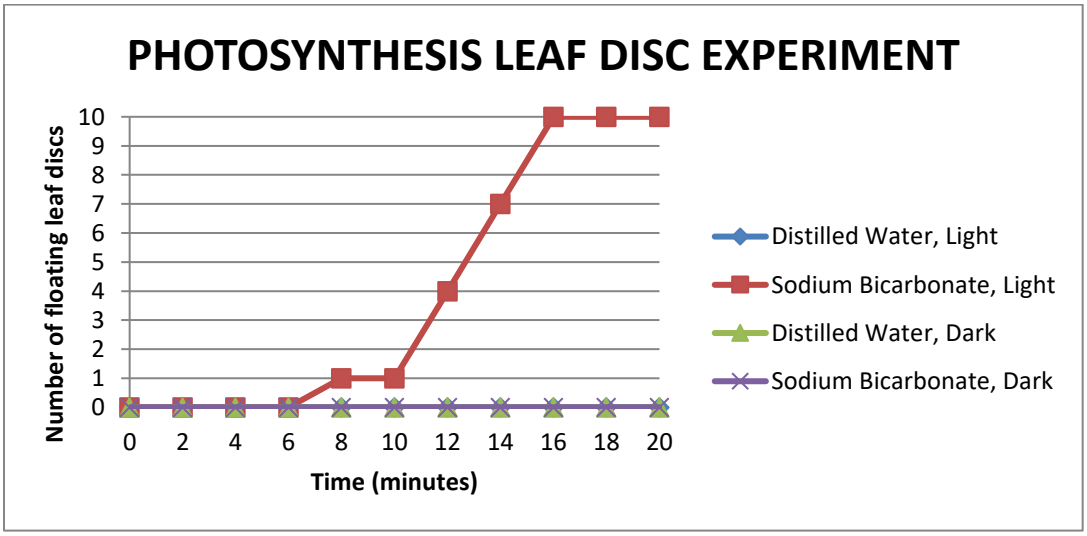
At the start of the experiment, all leaf discs were at the bottom of the cups. As soon as one cup of distilled water solution and one cup of sodium bicarbonate solution with the leaf discs were placed under a light source, the number of floating leaf discs in each cup was observed and recorded every two minutes. This was carried out for a total of 20 minutes. The results were recorded and are given in Table 1 below.

Time (min)	Distilled water, light: # of floating disks	Sodium bicarbonate, light: # of floating disks	Distilled water, dark: # of floating disks	Sodium bicarbonate, dark: # of floating disks
0	0	0	0	0
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	1	0	0
10	0	1	0	0

12	0	4	0	0
14	0	7	0	0
16	0	10	0	0
18	0	10	0	0
20	0	10	0	0

Table 1: Number of leaf discs in each of the 4 cups labelled 'Distilled Water, Light', 'Sodium Bicarbonate, Light', 'Distilled Water, Dark', and 'Sodium Bicarbonate, Dark'.

From Table 1, it can be seen that the spinach leaf discs were found to float in just one cup which had the sodium bicarbonate solution and was kept under a light source proving that photosynthesis had taken place only in this cup. Using the results, a graph was plotted which is presented below.



Graph 1: Photosynthesis Leaf Disc Experiment – The graph shows a plot between time in minutes and the number of floating leaf discs in four different experimental setups. As seen in the graph, leaf discs in the 'Sodium Bicarbonate, Light' cup were seen to float with the passage of time which is indicative of photosynthesis in this cup.

After 20 minutes of beginning the experiment, the cups that were placed in the light source were transferred to a dark cabinet. The number of leaf discs that were floating in each cup was counted every 2 minutes for a total of 20 minutes. The results were recorded and are given in Table 2 below.

Time (min)	Distilled water, light: # of floating disks	Sodium bicarbonate, light: # of floating disks

0	0	10
2	0	8
4	0	7
6	0	7
8	0	6
10	0	5
12	0	4
14	0	2
16	0	0
18	0	0
20	0	0

Table 2: Number of floating discs after transferring distilled water solution and sodium bicarbonate solution cups from light source to a dark cabinet

As seen in Table 2, after transferring the distilled water solution and sodium bicarbonate solution cups from the light source to a dark cabinet, the leaf discs gradually begin sinking to the bottom of the cups. By the end of 20 minutes, there are no leaf discs floating in either cup.

Discussion

Plants require light, water, and carbon dioxide for performing photosynthesis. In this experiment, the light is provided by the light source which is the desk lamp, water is provided from the solution, and dissolved carbon dioxide is provided from the sodium bicarbonate solution. In the absence of even one of the raw materials, photosynthesis does not take place.

Plant materials generally float in water because leaves have air spaces present between cells through which they acquire carbon dioxide from the environment. When a vacuum is created in the solution where the leaves are suspended, the air in the leaves is sucked out and replaced with solution which makes the leaf discs sink to the bottom of the cup. Hence, at the beginning of the experiment, all leaf discs are present at the bottom of their respective cups.

When two cups containing distilled water solution and sodium bicarbonate solution are placed under a light source, the leaf discs suspended in the sodium bicarbonate solution receive all the raw materials required for photosynthesis. Therefore, the leaf discs in the cup labelled ‘Sodium Bicarbonate, Light’ start photosynthesizing, generating oxygen as a byproduct. This oxygen accumulates on the surface of the leaves in the form of tiny bubbles which causes them to start floating. The cups that are placed in the dark do not receive light, in the absence of which photosynthesis cannot take place. Also, the leaf discs suspended in distilled water solution lack

carbon dioxide and so, even though the cup is placed under a light source, the absence of carbon dioxide results in no photosynthesis taking place.

When the floating leaf discs are transferred from a light source to a dark cabinet, the absence of light causes all photosynthetic reactions to stop. As a result, no more oxygen is produced and the oxygen that is already present on the leaves is used up in cellular respiration processes which generate carbon dioxide as a byproduct. This carbon dioxide goes into solution more easily than oxygen resulting in the floating leaf discs sinking to the bottom of the cup.

Conclusion

In this experiment, it was proved that light, carbon dioxide, and water are all essential for photosynthesis in plants and the absence of any one source results in no photosynthesis taking place. Keeping water as a constant, the presence of light and carbon dioxide sources were varied to observe the presence or absence of photosynthesis in different experimental setups.

In the cups that were placed in a dark cabinet, no leaf discs were found to rise indicating that photosynthesis cannot take place in the absence of light. Among the cups that were placed under a light source, the leaf discs that were suspended in distilled water solution did not float as they lacked a carbon dioxide source for photosynthesis. Hence, this shows that photosynthesis cannot take place in the absence of carbon dioxide. In the cup where the leaf discs are suspended in a sodium bicarbonate solution, the leaf discs begin floating after 6 minutes indicating that photosynthesis is taking place in this cup. During the process of photosynthesis, carbon dioxide from the solution is converted into oxygen which replaces the carbon dioxide within the spaces of the leaves causing the discs to rise to the top.

When this cup was transferred to the dark, no more photosynthesis was taking place resulting in no further production of oxygen. However, the cellular respiration processes were taking place which consumed all the oxygen generated by the leaves leaving the air spaces within the leaves empty causing them to sink to the bottom.

Exercise 2: Investigating Photosynthesis

Introduction

Light is one of the most important raw materials for photosynthesis wherein solar energy is converted into chemical energy by plants. The rate of photosynthesis depends on several light-related factors such as angle of sunlight and wavelength of solar radiation. Very high and very low intensities of light are harmful to the photosynthetic components of plants and they can halt or reduce photosynthetic reactions taking place in the leaves. A lot of plants have several techniques to deal with low-light and high-light conditions such as anatomical changes to enhance light capture in shady areas and repairing mechanisms to protect cellular machinery from the harmful and intense radiation of the sun.

In this experiment, it has been hypothesized that variation in light intensity affects the rate of photosynthesis in spinach leaf discs. When the light energy is available in a larger amount to the plant, the chloroplasts will operate at a faster rate converting carbon dioxide and water to glucose and oxygen. This process can be seen by observing the bubbles formed in the solution in which the leaf discs are suspended which indicate the amount of oxygen produced. Here, the buoyancy of the leaf discs is noted to determine the rate of photosynthesis under different light intensities. By keeping the source of light and availability of water and carbon dioxide constant, it is ensured that changes in the rate of photosynthesis are only due to variation in the intensity of light. The light intensity is adjusted by means of distance of the leaf discs from the light source and the time taken for the leaf discs to achieve buoyancy for two different light intensities is observed.

Materials

- Two plastic cups containing sodium bicarbonate solutions with leaf discs (to be reused from the previous exercise)
- Desk lamp with an incandescent light bulb
- Ruler
- Timer

Methods

1. A desk lamp was set up on the workspace and with the help of a ruler, two points of 10 cm and 20 cm each from the light source was marked with a pencil.
2. A plastic cup containing the sodium bicarbonate solution with all the leaf discs at the bottom was placed at the 10 cm mark and the timer was started.

3. The timepoint at which the first leaf disc and the last leaf disc started floating was noted.
4. The second cup containing the sodium bicarbonate solution with all the leaf discs at the bottom was placed at the 20 cm mark and the timer was started.
5. The timepoint at which the first leaf disc and the last leaf disc started floating was noted.
6. The results were tabulated and compared.

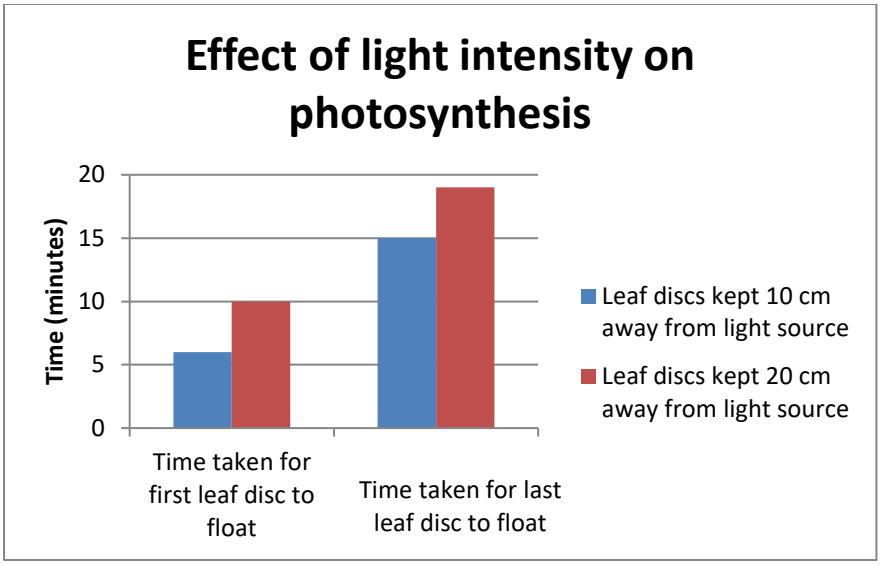
Results

In this experiment, the light intensity was varied by varying the distance of the leaf discs from the light source keeping the source of carbon dioxide constant. The time taken for the first and last leaf disc to start floating while keeping the leaf discs 10 cm and 20 cm away from the light source respectively was noted. The results are given in Table 3 below.

	Time taken for first leaf to start floating (minutes)	Time taken for last leaf to start floating (minutes)
Leaf discs kept 10 cm away from light source	6	15
Leaf discs kept 20 cm away from light source	10	19

Table 3: Time taken for the first and last leaf disc to start floating keeping the leaf discs at a distance of 10 cm and 20 cm from the light source

It can be seen from Table 3 that with the decrease in intensity of light, the time taken for the leaf discs to start floating increases. This shows that a greater intensity of light fastens the rate of photosynthesis in leaf discs. Given below is a bar graph demonstrating the effect of light on the rate of photosynthesis.



Graph 2: Bar graph demonstrating the effect of light intensity on photosynthesis. The blue bars indicate the leaf discs kept 10 cm away from the light source and the red bars indicate the leaf discs kept 20 cm away from the light source.

Discussion

Light intensity is an important factor that governs the rate of photosynthesis. In this experiment, a rough idea of the rate of photosynthesis can be acquired in varying intensities of light. When the leaf discs suspended in sodium bicarbonate solution were placed 10 cm away from the light source, the first leaf disc started floating at 6 minutes and by 15 minutes, all the leaf discs were floating. This shows that as a result of photosynthesis, oxygen accumulated on the surface of the leaf discs causing them to float.

When the leaf discs suspended in sodium bicarbonate solution were placed 20 cm away from the light source, it was seen that the first leaf disc started floating at 10 minutes and it took 19 minutes for all the leaf discs to start floating. As compared to the previous setup, the time taken for the leaf discs to start floating was more indicating that the rate at which photosynthesis occurred was directly influenced by the intensity of light. At greater light intensity, photosynthesis occurred at a faster rate and at lower light intensity, photosynthesis occurred at a slower rate.

Conclusion

Light can act as a limiting factor when the light intensity is too low to allow photosynthesis to occur at its maximum rate. This is true for plants in shady areas where the light intensity is generally low causing photosynthesis to proceed at a slower rate. On the other hand, if the intensity of light is too high, bleaching of chlorophyll may take place slowing the rate of

photosynthetic reactions. High light intensities can also cause saturation in the active sites of enzymes causing photosynthetic reactions to come to a standstill.

In this experiment, the rate of oxygen produced was used to ascertain the rate of photosynthesis in spinach leaf discs. Although it is not a very accurate measure, a comparison between the time taken for leaf discs to start floating under varying light intensities gives an idea of the difference in photosynthesis rates under different light conditions. As the time taken for the first leaf to start floating showed a difference of 4 minutes when the distance to the light source was increased, it can be assumed that the light intensity is directly proportional to the rate of photosynthesis.

There are a lot of other factors that may affect the experiment. It should be ensured that light from other sources is minimal so that additional light energy does not contribute to the progression of photosynthesis. The temperature of the experimental area should be constant as even a slight increase in temperature can result in an increase in the rate of photosynthesis. Minor disturbances like these may affect the experimental results causing interpretational errors in differences in the rates of photosynthesis.