Most Optimal Environment for Photosynthesis and Oxygen Production

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ABSTRACT: The purpose of this study was to discover what environment is best for photosynthesis and oxygen production in plants. In order to answer the question about which environment is most optimal, I conducted an experiment that tested four different environments: an acidic, acetic acid-rich, moving environment, (bubbled vinegar) an acidic, acetic acid-rich, still environment, (still vinegar) a neutral, moving, raw material-containing, environment, (bubbled water) and a neutral, unmoving environment (still water). I made a 0.2% sodium bicarbonate solution and placed 10 leaf discs, along with the solution, in a plastic syringe, creating a vacuum so that the leaf discs could be drained of the air from the air spaces in the leaf, filling those spaces with the bicarbonate solution. Then, to measure the rate of photosynthesis and the rate of oxygen production of plants, I placed 10 leaf discs in each of the simulated environments and recorded the amount of time it took for each of the leaf discs to rise, performing a statistical analysis on my results found. I found that the leaf discs in the bubbled vinegar rose at the quickest rate, then the leaf discs in the still vinegar were next, then the leaf discs in the bubbled water, and lastly the leaf discs in the still water rising at the slowest rate. These results mean that photosynthesis proceeded at the quickest rate in the bubbled vinegar, and at the slowest rate in the still water.

KEYWORDS: Biology; Cellular Processes; Photosynthesis; Cellular Respiration; Oxygen Production.

Introduction

My topic was how the bubbling of water and vinegar affects the rate of photosynthesis and in turn, oxygen production in plants, since oxygen is a beneficial product of photosynthesis. Photosynthesis is a process in which carbon dioxide and water is converted into glucose, a fuel molecule, through the use of enzymes and light. “Photosynthesis is the process used by plants, algae and certain bacteria to harness energy from sunlight and turn it into chemical energy”.[1] Light is necessary for photosynthesis because it allows for the splitting of water, thus allowing for photosynthesis to lock the necessary energy into sugars for plants to us. Based on the use of different enzymes and environmental factors, the process of photosynthesis can be accelerated or slowed. Environmental factors can lead to the quicker uptake of substrates and conversion into products, so that glucose can be produced at a faster rate, leading to a quicker rate of cellular respiration. Environmental factors explored in this experiment include surveying the effect vinegar has on the rate of photosynthesis versus the effect water has on the rate of photosynthesis, as well as the differences in the rates of photosynthesis based on whether or not the environments were moving or nonmoving. Vinegar was chosen because it contains acetic acid and acetate, which affect acidity and the rate of cellular respiration, thus also affecting the rate of photosynthesis. A moving environment was simulated by bubbling two of the environments tested. It was predicted that bubbling an environment would cause a rapid exchange of materials between the test environment and the surrounding environment, thus leading to the quicker uptake of the raw materials of photosynthesis, producing a faster rate of photosynthesis. The surrounding environment contains numerous gases, some of which are beneficial to photosynthesis, and others that are harmful to it. Vinegar and the bubbling of an environment are significant variables for studying photosynthesis and how it can be accelerated because while these environments are simulated, there are very similar environments in the natural world that can be utilized so that photosynthesis can increase, yielding a higher crop yield for food production and leading to an overall decrease in carbon dioxide in the atmosphere.

I chose this topic because it is important for humans to know what environments are best for photosynthesis and cellular respiration, thus leading to more optimal living conditions for humans and other species. “Some 80% of the world’s wastewater is dumped—largely untreated—back into the environment, polluting rivers, lakes, and oceans”.[2] Since our oceans, lakes, and rivers are being contaminated everyday due to toxins, which include “pathogenic microorganisms, putrescible organic waste, plant nutrients, toxic chemicals, sediments, heat petroleum (oil), and radioactive substances”[3] and are in turn harming the creatures that live in them, it is important we know which environments are best for cellular respiration and photosynthesis, so that we can best utilize those environments for the betterment of the quality of life for all organisms on Earth. Although cellular respiration will not be adversely affected until oxygen concentrations are very low, it is still important to know that pollution can harm an organism’s rate of cellular respiration by blocking specific biologic and chemical pathways, leading to that organism not being able to utilize the available oxygen. An overall increase in the rate of photosynthesis will lead to an overall decrease in the amount of carbon dioxide in the environment. Carbon dioxide has been increasing over the years due to fossil fuels, and the general decrease of carbon dioxide would lead to an overall better quality of life for all species on Earth. The quality of life would increase for many species because the increase in fossil fuels has led to a dramatic increase on the overall temperature of the Earth, leading to many species dying and suffering, due to habitat loss and other damaging occurrences. If the overall amount of carbon dioxide decreased, then the overall temperature of the Earth would stabilize as well, leading to species being able to flourish. We can then utilize our resources and efforts in environments where cellular respiration and photosynthesis are most optimal, promoting an overall decrease in carbon dioxide in the atmosphere.

If the acetic acid or acetate in the vinegar increases the rate of photosynthesis, it could then be applied to environments in real life situations, leading to a general decrease in the overall amount of carbon dioxide on Earth and an overall increase in crop production. This would also help damaged environments because we could alter the conditions of the water so that those organisms will have healthy habitats and would thus be able to perform cellular respiration and photosynthesis at more efficient rates. If the organisms in those bodies of water are healthier, those organisms will be able to perform many biological processes at more efficient rates. "With an increase of oxygen concentration in the atmosphere, the rate of respiration also increases".[4] While this may be true, it will only be a significant difference when the amount of oxygen goes from a very low concentration, to one of a much higher concentration. When oxygen levels are low, carbon dioxide levels are higher, leading to a more optimal rate of photosynthesis, since conditions for this process are more ideal. When carbon dioxide levels are low, oxygen levels are high, thus promoting better conditions for cellular respiration.

I wanted to find out which environment photosynthesis is most efficient and produces the greatest amount of oxygen as a product. The setup that produced the greatest amount of oxygen as a product would also be the setup that consumed the most carbon dioxide. When photosynthetic rates are at a high level, its products, glucose and other fuel molecules, are in a high abundance. This means that cellular respiration can occur at a quicker rate because it has more of a raw material, glucose. When there is a high level of nutrient availability, light, and water, photosynthesis can proceed at a fast rate as well. The raw materials for photosynthesis are carbon dioxide and water. The relationship between the amount of raw materials and the rate of photosynthesis can be described as a positive correlation. When carbon dioxide increases, it causes a rapid rise in the rate of photosynthesis.[5] Photosynthesis can be affected by many factors, including temperature, light, and concentrations of certain chemicals.

The research question being asked is how does the bubbling of water and vinegar affect the rate of photosynthesis, measured by the time it takes basil leaf discs to rise. The basil leaf discs were all of uniform size and shape, thus providing a control as to how photosynthesis was measured. The leaf discs that were used in the experiment did not have veins in them, since that is where the vascular bundles mainly are, and as a result, would not have led to an accurate representation of the rate of photosynthesis. The null hypothesis is there will be no difference in the rates in which leaf discs rise between any of the setups. Since vinegar does not contain carbon dioxide, it may have no effect on the rate of photosynthesis and the bubbling of the setups may not be strong enough to cause the exchange of raw materials between the setups and the surrounding environment. The alternative hypothesis is the leaf discs in the bubbled vinegar will rise at the fastest rate, the discs in the bubbled water at the second quickest, the discs in the still vinegar next, and the leaf discs in the still water at the slowest rate. Since the bubbled vinegar contains acetic acid, this may affect the acidity of the carbon dioxide, promoting a quicker rate of photosynthesis and the bubbling may lead to the exchange of materials with the environment, leading to the leaf discs having access to the raw materials of photosynthesis faster. Research has been performed that has shown that acetic acid increases leaf growth, thus increasing photosynthetic activity, when it was used at appropriate levels.[6] The acetic acid may also have a positive effect on the rate of cellular respiration, when used at appropriate amounts, and thus allowing for the raw materials of photosynthesis to be more readily available. In other experimental studies involving mung bean plants, it was shown that acetic acid allowed for an increase in plant growth, thus allowing for an increased rate of photosynthesis.[7] Thus, if the results of the alternative hypothesis prove to be true, acetic acid could be used as a way to increase crop production in a real-life situation, which would also lead to an overall decrease in carbon dioxide in the environment. The discs in the bubbled water will rise next because the exchange of raw materials will most likely be quicker and the discs will have greater access to the raw materials than the discs in the still vinegar. The discs in the still vinegar will follow because the effect of the acetic acid on the acidity on the carbon dioxide will lead to a faster rate of photosynthesis, but not probably as fast as the effect the exchange of materials with the environment through bubbling had on the rate of photosynthesis. The discs in the still water will rise at the slowest rate because there is no exchange of raw materials with the environment and there is no acetic acid affecting the acidity of the solution. The independent variable is the bubbling of water and vinegar, while the dependent variable is the rates at which the leaf discs rise (photosynthesis). The control group are the groups that are not being bubbled and the experimental groups are the groups that are being bubbled. Controlled variables include the temperature at which the experiment was performed at, the amount of light each setup was given, the type of plant used for the leaf discs, and the amount of the 0.2% sodium bicarbonate solution used for each test.

Results and Discussion

The average amount of time it took for leaf discs to rise in bubbled water was 700.7 seconds, in the bubbled vinegar it was 56.612 seconds, the leaf discs took 1410.17 seconds to rise in the water that was not bubbled and in the vinegar that was not bubbled, the average amount of time it took for the leaf

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discs to rise was 97.60 seconds. Although the two standard error bars do overlap for the bubbled water, still vinegar, and bubbled vinegar, they do not overlap with the still water, so the rate of photosynthesis still occurs at a faster rate in the bubbled vinegar, still vinegar, and bubbled water than it does in the still water. The alternative hypothesis is also not fully correct because in that hypothesis, I predicted that the leaf discs in the bubbled water would rise faster than the leaf discs in the vinegar that was not bubbled, but the leaf discs in the still vinegar rose faster than bubbled water. Although the leaf discs in the still vinegar rose at a faster rate than in the bubbled water, the rest of the alternative hypothesis is true; that the leaf discs rose at the quickest rate in the bubbled vinegar, and they rose at the slowest rate in the still water.

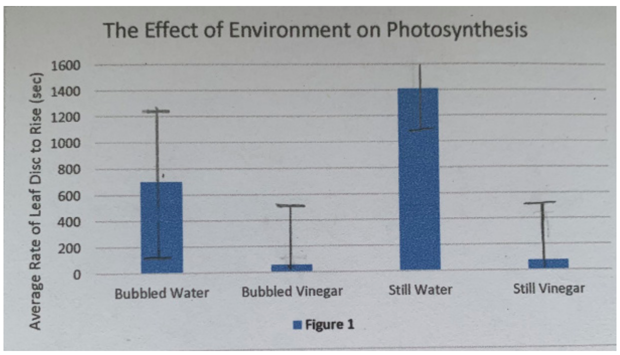

Figure 1: Graph showing the average amount of time it took for each leaf disc to rise in each setup

Time to Rise (Seconds)

Trials	Bubbled Water	Bubbled Vinegar	Still Water	Still Vinegar
1	16	0	1	0
2	16	0	1	0
3	310	0	25.7	0
4	416	15.1	461	3
5	485	21.02	1512	3
6	617	22	2340	92
7	1059	23	2425	116
8	1148	73	2448	117
9	1440	134	2589	118
10	1500	278	2760	305
Mean	700.7	56.612	1410.17	75.4
Standard Deviation	551.6	88.3	1200.1	97.6
Standard Error	174.4	27.9	379.5	30.9
Two Standard Errors	149.1 - 1252.3	(-31.7) - 144.9	256.2 - 2656.3	(-22.2) - 173.0

Figure 2: The results from each test and the statistical tests performed

Conclusion

Elucidating environments that are most optimal for photosynthesis and cellular respiration can promote further experimental research into finding out which environments are best for photosynthesis in real-life situations. If we can test different environments in the natural world then we may know more specific conditions for which bodies of water would allow organisms to perform photosynthesis and cellular respiration at the most efficient rates, thus having the most optimal living conditions. Although optimal living conditions for those organisms may not seem limited, many of those aquatic environments are "as inaccessible as if they were on Mars, and those that are accessible are unevenly distributed across the planet".[9] Combined with pollution in the available water, leading to organisms dying, due to the pollution blocking necessary biologic and chemical pathways, it is imperative that a solution is developed. Air pollution negatively affects photosynthesis because it reduces the size of a plant's stomata, leading to a decrease in gas exchange between the plant and the environment. A decrease in the amount of carbon dioxide available to the plant could lead to an impairment in photosynthesis.[10] So even if there was enough available carbon dioxide and oxygen in the surrounding environment, it would be inaccessible to the plant, due to pollution causing the stomates in plants to close, an area where major gas exchange occurs, leading to its death and a decrease in the amount of photosynthesis and cellular respiration taking place on Earth.

To apply this experiment to a real-life situation, we could experiment with environments that were similar to those that were tested. The acetate in acetic acid could be tested for its effects on leaf growth and thus its effects on photosynthesis and cellular respiration and survey how it affected plant growth and crop turnover, seeing if overall crop production could increase, leading to an overall increase in the quality of life for all species, due to the increase in the overall food available, and the decrease in the amount of carbon dioxide in the air, that would be being used by the extra crops for photosynthesis. In the lakes in the Adirondacks, as the air pollution has decreased, the health of many of the lakes has improved, after many years of pollution destroying the lakes and killing many fish.[11] Due to many forests all around the world burning down, the amount of carbon dioxide in the atmosphere has greatly increased, due to the trees and other photosynthetic organisms in those destroyed forests no longer offsetting the extra carbon dioxide that results from fossil fuels, since their photosynthesis was lost. The burning of the forests also released carbon dioxide into the air, further contributing to the increase in temperature. Although acids with a similar pH result in a decrease in pH, since the acetate in the vinegar has an optimal pH for photosynthesis, photosynthesis will still proceed at an optimal rate. Due to the acetate in acetic acid having an optimal pH for plant growth and photosynthesis, the rate of photosynthesis will increase in the presence of acetate, leading to an increase in overall plant growth, and a general decrease in the overall levels of carbon dioxide in the atmosphere, due to the increase in photosynthesis. As a result, the overall temperatures would decrease, thus prompting an increase in the quality of life for all species on Earth.

To expand on the experiment that was conducted, I would research other conditions, besides moving versus nonmoving liquids, in which photosynthesis and cellular respiration would be most optimal. Some other variables that I could research would be the pH of an environment, if specific organisms have different needs/have different environments that are most optimal, or if different temperatures impact the rates of photosynthesis and cellular respiration. If the environment best for photosynthesis and cellular respiration can be established, we can then know which environment is most optimal for those organisms and the organisms in surrounding areas.

Methods

The first step in my experiment was to fill two beakers, one with 500mL of vinegar, and the other with 500mL of water. I bubbled these beakers for two days. The second step was to fill another two beakers, one with 500mL of vinegar, and the other with 500mL of water. I let these beakers sit for two days. I then prepared a 0.2% sodium bicarbonate solution by mixing 300mL of water with 1 teaspoon of baking soda. I placed one to three drops of soap in the solution, avoiding the drops to be very bubbly. The fourth step was to create a vacuum in a plastic syringe. First, using a hole punch, I made 10 leaf discs out of a basil leaf, avoiding veins. Then, I put these 10 leaf discs in the plastic syringe. Next, I drew in 10mL of the 0.2% sodium bicarbonate solution, leaving some air. I held my finger over the narrow syringe opening while drawing back the plunger. I held the plastic syringe for ten seconds and I swirled the leaf discs. I released the vacuum by raising my finger off the end. I repeated these three more times for the other three beakers. The fifth step was to place a lamp 22 cm away from the four cups, each cup having its own setup; 100 mL of bubbled vinegar in 1 cup, 100 mL of bubbled water in 1 cup, 100 mL of vinegar that was not bubbled in 1 cup, and 100 mL of water that was not bubbled in 1 cup. I placed ten leaf discs in each setup, that had previously been in the syringe, and waited until they reached the bottom. I placed a lamp over each cup and recorded the amount of time it took for each leaf disc to rise in each setup.[12]

To determine as to whether or not there was a statically significant difference in the data found, I calculated the mean of the data values for each setup, taking note that there were no significant outliers in the data found, so I determined that the best way of representing the data was by finding the mean, instead of the median. I then calculated the standard deviation of the data values, to see how uniform or varied the data was. Lastly, I calculated two standard errors and plotted the means of the data, as well as two standard error bars. Although the two standard error bars overlapped in the still vinegar, bubbled vinegar, and bubbled water, they did not overlap with the error bars for still water. Therefore, the rate of photosynthesis was faster in the still vinegar, bubbled vinegar, and bubbled water than in the still water.

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Sydney Haas is a tenth grader at Victor Senior High Sch ool. She has grown up around water her whole life and has a deep appreciation for it. She hopes to make a difference in how the oceans are treated.

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