The comparison of hydrogen peroxide, grapeseed oil, and light as preventatives of algae in hydroponics.

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Abstract

The purpose of this project is to conduct research to find the best way to reduce, and potentially prevent, algae growth in hydroponics systems. This is important because the growth of algae in hydroponic systems is prominent and can be detrimental to the plant's uptake of nutrients. Algae can also buildup in piping and result in costly repairs to the hydroponics system. To perform this test, the researcher investigated how hydrogen peroxide, grapeseed oil, and limited light would impact algae growth, while also considering the impact these additives had on lettuce plant growth and the root growth. The control for the experiment was a clear container without any algae prevention additives. The procedures included germinating lettuce seeds, building four wick hydroponic systems, transplanting the plugs, and completing the trials. Five plants were used in each trial hydroponic system. Algae growth was evaluated by visual color and by counting the colonies utilizing Eggzamin counting slides under the microscope. Plant growth and root growth was also measured. The average results showed that algae growth was best controlled by the following variables respectively: limited light (.77 colonies per quadrant (CPQ)), hydrogen peroxide (1.22 CPQ), grapeseed oil (5.08 CPQ), and the control (5.92 CPQ). Plant growth was the most as follows: limited light (13.6 inches (in)), control (13.15 in), grapeseed oil (7.35 in), and hydrogen peroxide (8.25 in). Root growth was the most as follows: limited light (11.3 in), control (9.25 in), grapeseed oil (7.5 in), and hydrogen peroxide (3.3 in). The hypothesis for the experiment was not supported. The researcher concluded that when considering all research questions (algae prevention, plant growth, and root growth), the most effective and efficient algae prevention plan is the use of limited light followed by grapeseed oil, the control, and hydrogen peroxide being last. Although hydrogen peroxide did prevent algae, the researcher determined it was detrimental to plant and root growth.

Introduction

The increasing popularity of hydroponically grown plants has brought attention to the upkeep of the system. One of the biggest advantages of hydroponic growing is water conservation (Teodoro, 2019). The water is easier to manage and regulate in hydroponics systems since it is not being constantly evaporated. The plants are usually placed in opaque containers, so less sunlight hits the water, causing it to receive less light energy. Reduced light lowers energy transfer for molecule excitement, resulting in reduced phase change of the liquid water, and yielding reduced overall water loss. When using the traditional crop growing method, producers face a higher rate of water loss. Crops grown in the soil constantly require damp soil. When sunlight hits the soil, the process of evaporation begins, and water is taken away from the source for plants (Teodoro, 2019). While there are many advantages to the use of a hydroponics system, the systems are more susceptible to algae build up. Algae can build up and cling to any surface. This means it is rare that any system can be considered safe from it once it gains a foothold. Hydroponics systems have a vulnerability to algae growth as the growth starts inside the container and can enter pumps. When this takes place, there are two main concerns: nutrient loss and oxygen levels. Algae will begin to utilize the environment for growth. A nutrient concentrated solution is used to replace the soil and provide sufficient nutrients to the plants. Once the algae enter the hydroponics unit, it feeds of the available solution and deprives the plants of valuable nutrients. On top of nutrient loss, dissolved oxygen levels can drop at alarming rates. This causes plants to start suffocating, and means they are weaker to fight off any other pathogens (Stephens, 2019).

Algae growth in hydroponics systems can be detrimental to the growth of the plants. It reduces the amount of nutrients in the water and prevents the plant’s roots from absorbing the nutrients. The researcher was experiencing these same issues with the school’s hydroponics system which was being overrun with algae. By conducting this research, the results of this study can be used to not only decrease algae colonies in hydroponic systems, but also improve the efficiency of the systems to help us become a more sustainable society. Hydroponics systems have regulated water and nutrient levels, it makes it much easier to manage than using a plot of land. Also, less harmful pesticides are used because many of these systems are used in inside facilities. Seeing that, hydroponics systems circulate a nutrient solution, one can easily add more of a nutrient concentrate or add water to dilute it. When growing in soil mediums, it can be difficult to keep the nutritional levels constant. If a field is overused, it can be nutrient deficient. It takes a greater amount of labor and monetary investment to restore nutrients to field than to maintain a hydroponics system. Although, using hydroponics does seem like the better alternative, there are a few downfalls. For example, algae and mildew growth are issues common in hydroponic systems. The inspiration for conducting this research was to find convenient ways to prevent or reduce algae populating in hydroponics systems. When people use hydroponics systems, they may not know how to get rid of algae colonies, so by testing grapeseed oil, hydrogen peroxide and limited light exposure, the researcher found which one best suited their needs. As hydroponic gardens are continuously becoming more popular, the researcher realized how important these results could be for anyone who wanted to get involved in plant sciences. Since more people are using these systems, they need to understand the benefits and the adverse effects.

Before beginning this project, the researcher found the impact algae can have on hydroponic gardens. Several studies that the researcher reviewed demonstrated how damaging it would be for the plants if the algae were not taken care of sufficiently. The researcher took this information into account when constructing their own hydroponics systems and when deciding which components to test for as algae growth inhibitors. Many sites suggested cleaning tips and ways to get rid of the algae temporarily, but the researcher needs a long-term solution. That is why grapeseed oil, hydrogen peroxide, and limited light exposure were chosen as the treatments. The researcher also wanted to see which additive would not only prevent algae, but also not negatively impact the lettuce plant's overall growth.

Literature Review

For those not involved in the world of hydroponics, many may be unaware of the struggles encountered with their use. Many systems, if not taken care of properly, are overcome with algae and mildew. The abundance of algae can lead to nutrient loss in the plants being grown. Algae growth is formed from the owner either not providing the right amount of preventatives or none at all. A misconception that comes with these systems, is the amount of cleaning that is needed between uses. By not cleaning them properly or efficiently algae particles will still be present when the newest batch of nutrients is added. This will cause the algae to bloom immediately with the provided light exposure and nutrient dense water. Even after consumers use these methods to prevent algae, it is still a constant issue being faced. Many may not realize the amount of unwanted problems that come with algae growth in hydroponics systems, but there are a few that can immensely affect the plants from all aspects. Algae will reduce the cultivation numbers and lessen the size of the roots and leaves. Also, depending on the type of system being used, algae can clog pipes and cause less circulation of oxygenated water. This leads to the suffocation of the plants and nutrient deprived roots. Algae will also cling to the sides of the net cups and then grow onto the roots. The mildew on the roots can also steal the nutrients from the plants and lead to less growth or less production from the system.

Hydroponics systems are used in many places where the sun is less prevalent or where the soil is not of quality necessary for growing crops. Hydroponics systems started in ancient times and progressed to the point of being used on space stations in outer space. These types of systems are used in places where there is not reliable soil or enough sunlight. On the space stations, there is neither soil nor sunlight. By using hydroponics systems in space, people other than scientists are learning how to better grow crops and or food. By using these systems in unlikely places, it also leads to better sustainability, which is especially key for the future, since we will need to feed over nine billion people by 2050. By using these systems instead of turning over plots of soil every year, farmers and scientists would not have to worry about the soil losing the nutrient density. Not only have hydroponics been used in unlikely places, but they have also been used for a long time. Hydroponics planted its roots thousands of years ago. The earliest recorded use of hydroponics was in the hanging gardens of Babylon. The way Babylonians used their hydroponic gardens influenced how people use them today. Since then, scientists have made improvements as technology has developed, including the electronic systems of the present. The ideas for these systems originated from the hanging gardens in Babylon. Furthermore, in a recent study, Timothy Tripp explained how Hydroponics systems were used in the 17th Century. He also wrote how Sir Francis Bacon and John Woodard published works about hydroponics systems. (Tripp, 2014). William Fredrick Gericke started to popularize that plants could be grown in nutrient solutions and water instead of soil (Teodoro, 2019). Gericke's research at Berkley University influenced the way many people grow crops today. Because he popularized these ideas, many farmers and scientists started taking his ideas and making them more sustainable. Their extensions also took past ideas and made them more acceptable and feasible to society. Also, TIME magazine featured hydroponic gardening in 1938 when soldiers in World War II used the techniques to grow food during battle. There are many ways hydroponics systems have been used in the past, with each helping to influence the uses and system designs of the present.

Since the modern world is becoming more and more progressive, many are starting to use hydroponics systems. As these are becoming more available, so as expected there are many pros and cons to using these types of systems. William Fredrick Gericke is the earliest modern researcher to experiment with hydroponics systems. His research has influenced many of the ways scientists experiment with and test hydroponics systems today. Gericke discovered that you could grow crops in just water, nutrients, and a growing medium. A great advantage of hydroponics is “lower water and nutrient costs associated with water and recycling” (Dunn, 2010). When plants are grown in the soil, the soil must maintain an acceptable level of saturation. To maintain this level of saturation, an abundance of water must be absorbed. If the soil is over saturated, the roots will not get enough oxygen and will drown. On the contrary, if the soil is under saturated, the roots will shrivel and the whole plant could die. When growing in soil many people can ruin their plots because they use too much of the resources (Espiritu 2019). For example, during The Great Depression, people in the mid-west had no choice but to continuously grow in the same plots of land. This practice did not give the soil time to replenish its nutrients. The soil became so dry that they could no longer grow crops there. Therefore, it is good for people to grow in water and nutrients with hydroponics. The practice that better suits the soil is crop rotation. Crop rotation is when a producer has multiple growing fields, but only grows crops on a portion for one year and then rotates to the next plot the following year. This practice ensures that nutrients can be replenished, and the soil is never depleted. Hydroponics can offer an alternative growing practice to ease the replenishing of nutrients and water for plants. A hydroponics system can recycle nutrients which makes for a quicker replenishing of nutrients for the system. Another advantage to using these systems is the abundance in types for all types of farming. A few examples are the Wick's systems, Ebb and Flow, and the Drip systems are a few different examples. Each type of system can provide the best service for whatever plant being grown. Also, the many options make it easier for the plants to grown and a healthier environment for them to be in. For example, the Wick's System, it is one of the simplest systems to use. It is a trough of water and a tray to hold the net cups, which hold the plants. The plants are able to soak up the nutrients from the water while being suspended above the water. This system is one of the easiest kinds to use if the consumer is new to using hydroponics systems (Sensorex, n.d.). Not only are these simple, but they are also very healthy for the plants because they are getting a constant amount of water supplied straight to the roots. The Ebb and Flow hydroponics system is a popular type used among home gardeners. These systems consist of a spacious bed, packed with rockwool or another substance that is good for nutrient consumption. These plant beds are periodically flooded with water and then recycled back through the pumps and reused. The recycled water provides more nutrients which makes the plants grow bigger and then provides more cultivation (Sensorex, n.d.). Finally, the Drip system is another easy-to-use system that provides the plants with a constant amount of water. The water is sent to the base of the plant, so the roots are constantly being fed. Also, this system can have a small or large amount of water pumped through the pipes depending on the amount needed (Sensorex, n.d.).

When building or buying a hydroponics system, scientists must be cautious of where it is placed. It must be in a place with good ventilation, so the plants are getting enough oxygen, but it should not be in a place with a lot of wind. When there is too much wind, the draft will bring in algae particles. Also, if the system does not have a grow light, it must be in a place with plenty of sunlight. The more sunlight means more plant growth, but it also means more algae growth. Many hydroponic farmers use clear containers for optimum growth, and so that they can observe root growth. Although it is nice to be able to watch them grow, clear buckets allow more sunlight, and allow for more algae to bloom. When trying to reduce the growth of algae in hydroponics, clear buckets are best suited for testing. Light exposure can be one of the major causes of algae growth in hydroponics systems. When growing plants in hydroponics systems, the only portion of the system that should be exposed to light is the plant itself. Exposure to light is one of the biggest issues with hydroponics systems. If the water is exposed to too much light it will produce more algae. This is due to the additional light energy available yielding more photon transfer, which increases photosynthesis initiation rates in the algae present within the water. However, if the system does not have enough light, the plant will not grow. Another way to reduce algae growth is to use opaque or solid-colored materials. This can help prevent any light from getting into the system. If algae cannot reach the nutrient dense water to photosynthesize, it will not bloom (Stephens, 2019).

When checking pH and EC in hydroponics systems, there are a few ways it can be done. pH is a value one should check constantly. The researcher made sure the pH was checked at least every other day. pH is the amount of acid in the water, and it affects the plant's ability to dissolve nutrients. If the pH is too low, it will not dissolve the nutrients well enough. Solubility is important because the roots can only take up nutrients that are dissolved in solution and cannot take up solid nutrients. The EC should also be checked consistently because the EC is the measure of salinity in water. If it is not constantly monitored, it could change drastically. Low EC symptoms can include stunted plant growth and leaf discoloration (Mattson, n.d). Either of these values can fluctuate very easily. That is why the pH and EC must be monitored frequently to keep them constant.

There was an extensive amount of research done before this project could be executed and one of the main topics was different preventatives. Many of the studies and sites examined gave a cleaning alternative or a temporary fix, but the researcher was looking for a more permanent solution. On Saferbrands.com an anonymous author gives multiple ways to reduce algae growth or help it not grow, but they were all cleaning methods or procedures that could be applied daily. Since the researcher was looking for a more permanent solution. Many articles included chemical, organic and natural methods that could be applied to the hydroponics systems, so that is why the research chose a solution from each section. The chosen preventives were grapeseed oil, food grade hydrogen peroxide and limited light exposure. Grapeseed oil was the organic solution and was promoted by many healthy lifestyle websites and articles. Grapeseed oil has shown immense efficiencies when it comes to reducing algae growth. Not only does it reduce algae growth, but it is also safe for the plant's growth if used in low dosages (Stephens 2019). The second item chosen was Food Grade Hydrogen Peroxide, as the chemical-based product. There were a few other options for the chemical solution, but upon further study the research decided the hydrogen peroxide would be safest and the most effective for the plants. The dosage and type used should be lower on the scale, so it does not provide adverse effects to how the plants grow overall (Stephens 2019). The natural procedure applied to this experiment is limited light exposure. By using this method on the water alone, many researchers have had optimistic results and provided a large amount of the product for cultivation. Opaque items will cause less sunlight to penetrate through the material which therefore allows for less algae to photosynthesize (Stephens 2019). Not only is this healthier for the plant, but it also provides the consumer more of the product.

Materials and Methods

Materials:

- Seed Tweezers
- 1.5 inches Rock Wool Starter Plugs (1 sheet of)
- Seed Germination Dome
- Grow Light
- Spray Bottle
- Burped Lettuce Black Seeded Simpson seeds
- Four 17-quart clear storage boxes
- 3-inch net cups
- 1.25-inch net cups
- Grape Seed Oil (68 Fluid Ounces/ 2 liters)
- 12% Derived from 35% Food Grade Hydrogen Peroxide (16 fluid Ounces)
- Pipet
- Microscope
- Black Spray Paint
- Label Maker
- Eggzamin
- Flora Bloom Nutrient Solution (0-5-4)
- Flora Gro Nutrient Solution (2-1-6)
- Flora Micro Nutrient Solution (5-0-1)
- 76 mm Lenox Slot Hole Saw
- General Hydroponics pH Down
- General Hydroponics pH Up

- General Hydroponics pH Test Indicator
- TDS Meter
- LabQuest 2
- Tris- Compatible Flat pH Sensor
- Teaspoon measuring device
- 4-cup measuring cup.
- 100 Milliliter measuring cup
- Distilled Water
- Dish Soap
- Scrub Brush
- Small tray

Germination Process:

Before experimenting with ways to prevent algae colonies, one must germinate the lettuce seeds. To begin this process, gather the supplies: seed tweezers, 1.5-inch rock wool starter plugs (1 sheet of), a germination dome, a grow light, spray bottle, lettuce seeds (specific the researcher used was Burped Lettuce Black Seeded Simpson). Soak the rock wool in the bottom tray of the germination dome, letting it sit, fulling submerged in the water for 1 hour. After an hour has passed, take rockwool sheet out of water and use seed tweezers to place one lettuce seed in each hole. Pour the water out of the tray and put the rockwool back in the tray. Place the germination dome lid back on it and spray daily, making sure they are constantly wet. Let the seeds germinate in the dome for two weeks.

Growing Lettuce in the System Process:

Before growing the lettuce in the systems, one must purchase storage containers. Buy four 17- quart clear storage boxes with flat lids. Purchase matte black spray paint and apply a thick coat to one of the bins. Also, purchase three-inch net cups and 1.25-inch net cups. Cut five 76-millimeter holes into the lid with a 76-millimeter speed slot hole saw. After putting the systems together, one should rinse out the bins and fill them to the top line with distilled or clean water. The amount will be four gallons. Add a teaspoon of these three nutrient mixes: Flora Bloom Nutrient Solution (0-5-4), Flora Gro Nutrient Solution (2-1-6), Flora Micro Nutrient Solution (5-0-1). Combine well with the water and let it sit for at least 24 hours. After the water has set for one day, check the EC and pH.

To check EC levels, use a TDS meter and the EC level should be from 640- 840. Using the TDS meter, one should turn it on and click the mode button once. Then remove the lid of the meter and place in the water. Watch the screen and wait until the numbers stop moving. Record the number in US/cm. Complete process for each bin. To check pH, one should use a LabQuest and Tris-Compatible Flat pH Sensor. The pH level should be from 6.5-7.5. First, take the pH sensor and place it into channel one at the end of the LabQuest. Take the sensor out of the water solution and place it into each storage bin. Watch the numbers on the screen, waiting for them to stop, and then record the data. Repeat these tests for all trials.

After completing tests, place 3-inch net cups into the already cut holes in the lids. Put the freshly germinated seeds with the rock wool into the 1.25-inch net cups. Place the 1.25-inch net cups into 3-inch ones. Leave the seeds in the water for two weeks before adding any additives. Check the water levels, pH levels, and EC levels every day, making sure they are consistent. If the EC levels are too low add 1/3 of a teaspoon in whichever storage container has low data, but if the numbers are high, add distilled water, approximately one cup. If the pH is too high, add a teaspoon of General Hydroponics pH Down and if it is too low, add a teaspoon of General Hydroponics pH Up. Check the pH and EC at least every other day ensure it is constant.

After the lettuce has been in the system for two weeks, remove plants from bins. Dispose of the water and clean the storage boxes with soap and water. Be sure to clean any and all the algae out of the bins. After cleaning, fill the boxes back up with water and do the same process of adding the nutrients and letting it sit over again. While the water is setting, put the net cups with lettuce in a shallow tray with clean water. Before putting the plants back in, test the water and add the extra additives. Add two teaspoons of grapeseed oil and label the lid and bin determined for this preventative. Put 2.5 teaspoons of hydrogen peroxide and label the lid and bin in which it was added. Add the additives in at the beginning of every week. Put the lids back on and lettuce back in the systems.

Counting the Algae Process:

To begin counting algae colonies, one must purchase: Eggzamin slides. One should also buy a microscope or borrow one. They will also need to gather a pipet, small cup, microscope, and microscope slides. To begin this process, one must scrape all the sides of the bins to get the algae combined better with the water. Use a small cup to scoop some of the water. Plug in and turn on the microscope. Place the Eggzamin or blood cell counting slide on the microscope. Pick up a little bit of water with the pipet and squeeze it onto the slide, covering any and all sections. Adjust the microscope to focus on the algae colonies best. If using the Eggzamin slides, fill the entire square with water. Move the slide to count how many are in each column, starting from the left column. To gather data, count the largest groupings or colonies of ach column. If using the blood cell slides, count the largest groupings or colonies. Record this data as the first trial.

To get the data and information for the second trial clean the buckets out again and repeat the process to get the water ready again. Add the additives in and conduct an algae count every five days. Count the algae at least three times for every bin. By doing these tests at least three times, one will get more information and it will be more reliable.

Research Questions:

1. How do variables (hydrogen peroxide, grapeseed oil, and light) impact algae growth in hydroponics systems compared to the control (no preventative measure)?

2. How do variables (hydrogen peroxide, grapeseed oil, and light) impact lettuce plant growth in hydroponics systems compared to the control (no preventative measure)?

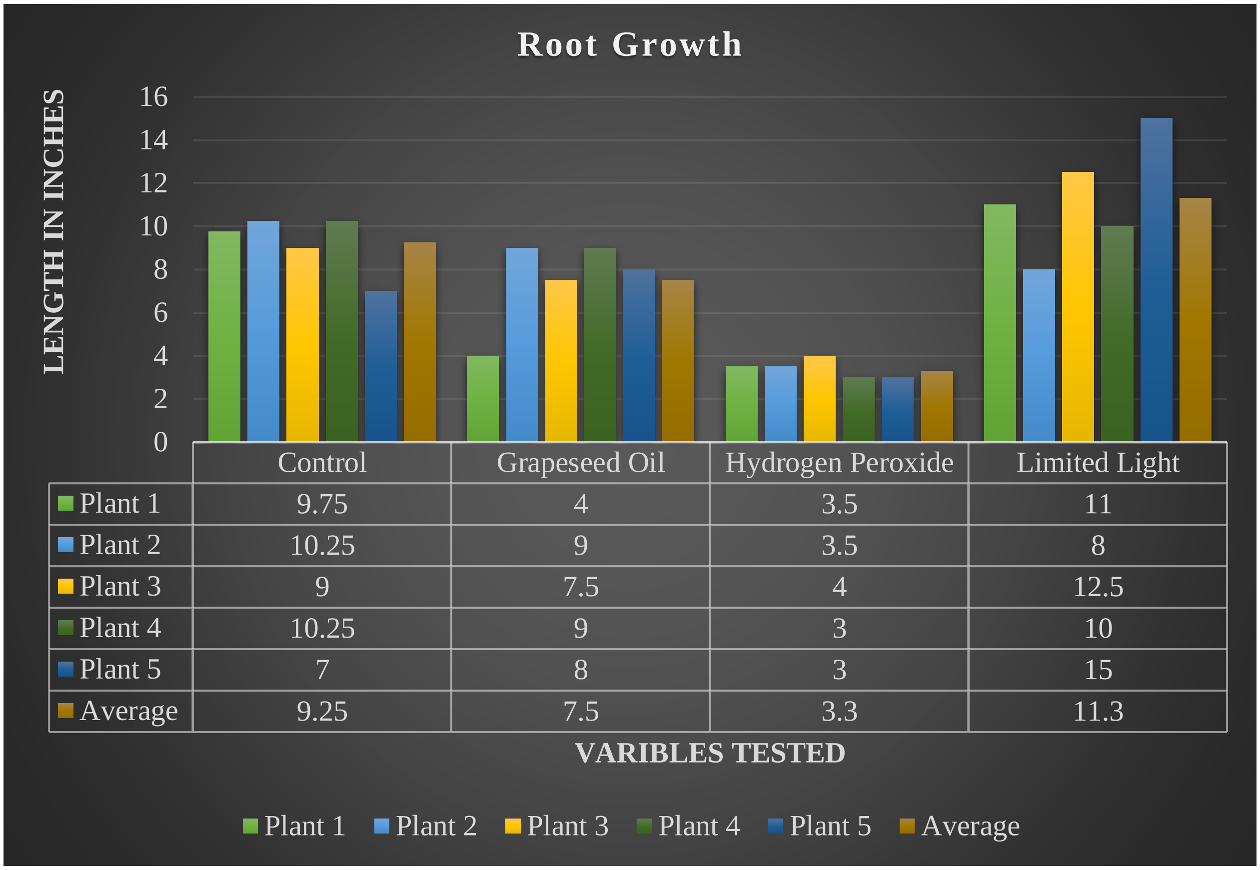
3. How do variables (hydrogen peroxide, grapeseed oil, and light) impact lettuce root growth in hydroponics systems compared to the control (no preventative measure)?

Hypothesis: If grapeseed oil, food grade hydrogen peroxide, and controlled light exposure is used to prevent algae growth, then the additives will make the overall algae counts less. Many researchers would be open to using natural processes, like limited light exposure, or organic options, such as grapeseed oil. Even though organic items may seem healthier for the plants overall, Hydrogen Peroxide will offer a better way to prevent algae growth. The researcher expected Hydrogen Peroxide to excel in algae growth prevention, followed by grapeseed oil, light, and the control (respectively.) Hydrogen peroxide will offer the overall most benefit when considering algae prevention, plant growth, and root growth.

Results

There were many results, common and uncommon, during this experiment. One common result was between the control system and the limited light exposure system. Both bins did not have any extra additives, but the limited light did have a different treatment. As seen in figures 1 and 2, the root and leaf growth were much higher. One can see in figure 1, the limited light test, had longer roots than the control. The researcher observed this system having less algae, as seen in figure 4. One can also see the differences by the qualitative results which systems had more algae and which ones had less. As seen in images 1-4, the systems had varying differences from the start. The first trial had significant differences between it and the second trial. As seen in figure 4, the data shows how much more algae started blooming in trial 2. The experimental average for the algae growth showed a definite result between all the systems. Even though the systems had same number of additives in each, the data shows differences between each trial. The root and leaf growth also show differences between the additives having positive and or adverse effects. These figures and images show both quantitative and qualitative results to account for the information the researcher supplied.

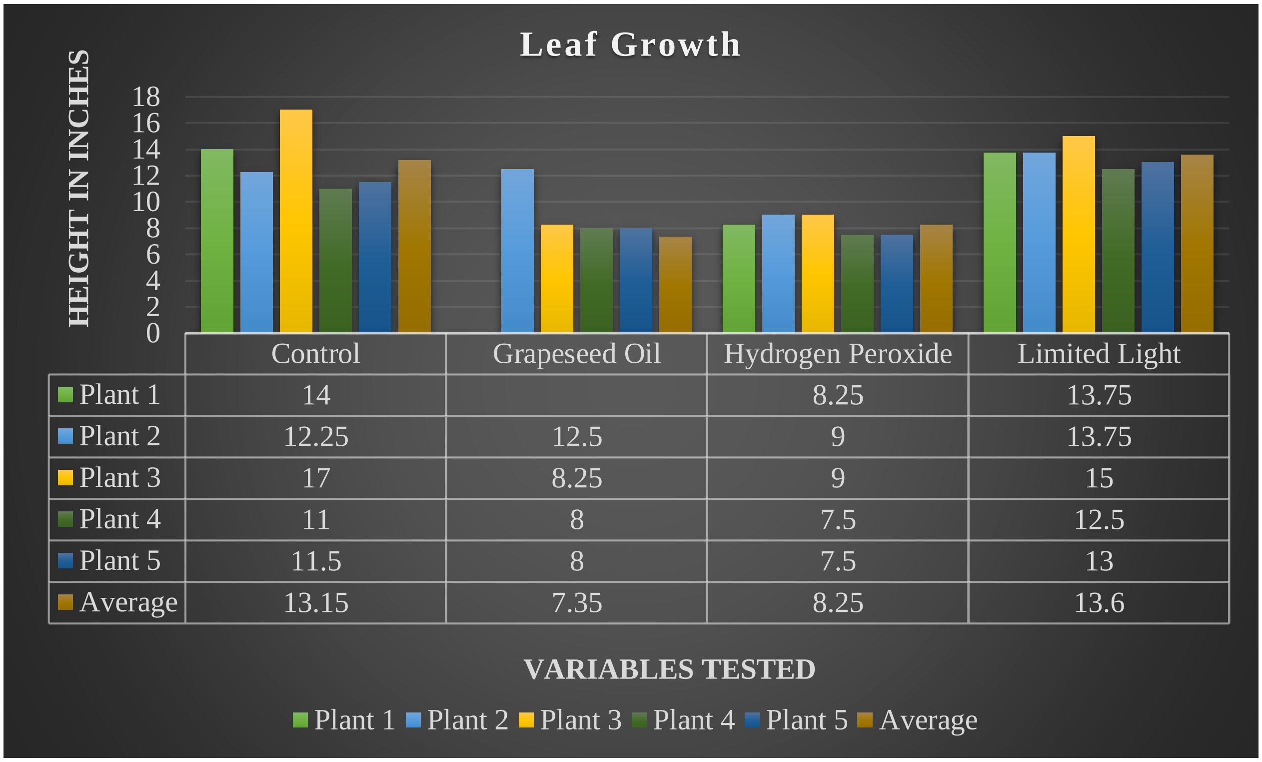
Root Growth Compared to the Variables Tested



	Control	Grapeseed Oil	Hydrogen Peroxide	Limited Light
Plant 1	9.75	4	3.5	11
Plant 2	10.25	9	3.5	8
Plant 3	9	7.5	4	12.5
Plant 4	10.25	9	3	10
Plant 5	7	8	3	15
Average	9.25	7.5	3.3	11.3

Figure 1

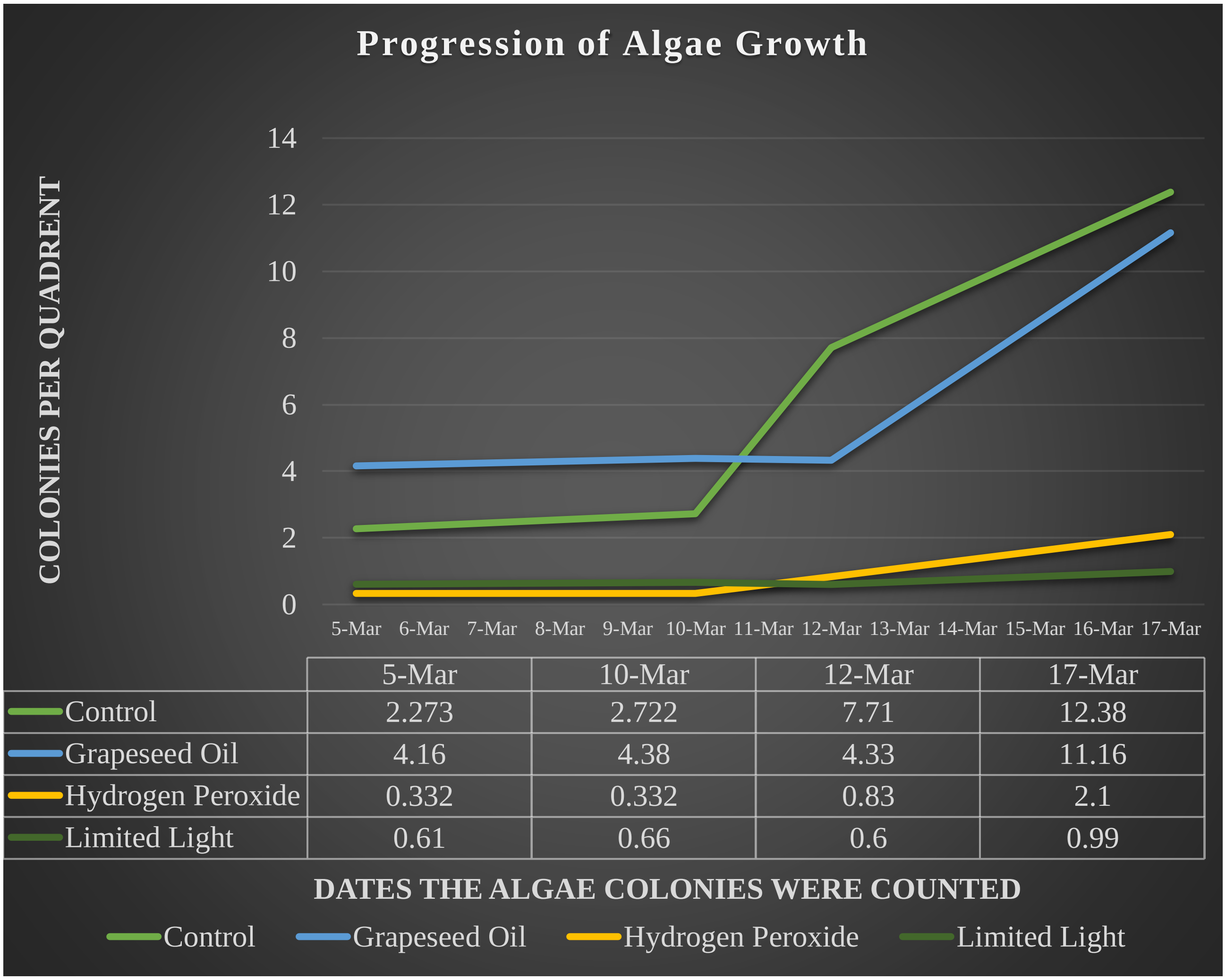
Plant Growth Compared by the Variables Tested



	Control	Grapeseed Oil	Hydrogen Peroxide	Limited Light
Plant 1	14		8.25	13.75
Plant 2	12.25	12.5	9	13.75
Plant 3	17	8.25	9	15
Plant 4	11	8	7.5	12.5
Plant 5	11.5	8	7.5	13
Average	13.15	7.35	8.25	13.6

Figure 2: The missing data in the grapeseed oil caterogory is due to the death of that particular plant. That value is considered an outlier, so it will not be considered in the final average.

Progression of Algae Growth compared by the Variables Tested



	5-Mar	10-Mar	12-Mar	17-Mar
Control	2.273	2.722	7.71	12.38
Grapeseed Oil	4.16	4.38	4.33	11.16
Hydrogen Peroxide	0.332	0.332	0.83	2.1
Limited Light	0.61	0.66	0.6	0.99

Figure 3

Final Algae Growth Averages by Variable

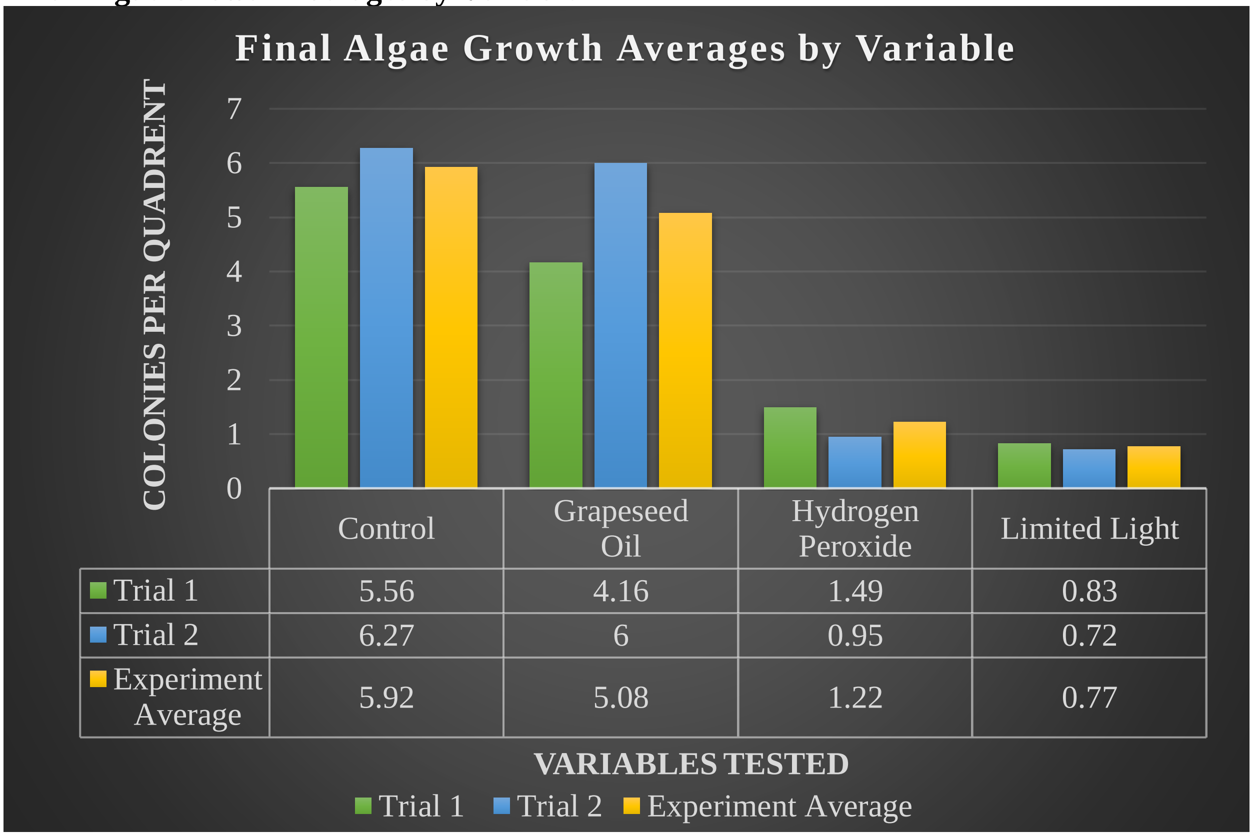


Figure 4

First Trial After Adding 3rd Dose of Additives

Image 1: (left to right) Control, Grapeseed Oil, Hydrogen Peroxide, Limited Light

Start of the Second Trial Before Adding Additives

Image 2: (left to right) Control, Grapeseed Oil, Hydrogen Peroxide, Limited Light

Middle of the 2^{nd} Trial After Adding Additives

Image 3: (left to right) Control, Grapeseed Oil, Hydrogen Peroxide, Limited Light

Day of the Final Trial

Image 4: (left to right) Hydrogen Peroxide, Control, Limited Light, Grapeseed Oil

Grapeseed Oil Roots

Image 5

Control Roots

Image 6

Hydrogen Peroxide

Image 7

Limited Light Exposure Roots

Image 8

Control System Leaf Visual

Image 9

Grapeseed Oil System Leaf Visual

Image 10

Hydrogen Peroxide System Leaf Visual

Image 11

Limited Light Exposure System Leaf Visual

Image 12

Discussion and Conclusions

During this experiment, the testing of hydrogen peroxide, grapeseed oil, and limited light exposure were tested to which was better for preventing algae growth. Before conducting these experiments, the researcher thought the hydrogen peroxide and grapeseed oil would be the best inhibitors of algae growth, but as the figures show, the limited light exposure was the most effective way to reduce the overall algae count. When including the additives, the researcher did not account for any of the extra supplements, other than the hydrogen peroxide, affecting the overall growth of the plant. The researcher also did not hypothesize any differentiations between the five lettuce plants in each system. Within each bin, the five plants had few differences, but in one of the systems testing with grapeseed oil, there was a distressed plant. It was not accounted for in the measurements for leaf growth, yet it still had roots, so the numbers were accounted for in that data.

In the first trial, initially the control had a much higher algae count over the grapeseed oil. Before starting the trials, the research hypothesized that the hydrogen peroxide would have the least number of algae, but upon further examination, the limited light had less than one colony per storage bin. Hydrogen peroxide was a viable alternative if the light could not be controlled. Although it did reduce the overall plant size, the algae count was less than two. If one examines figure 4, one can see the slight differences in the algae counts. Also, in figures 1 and 2, there are varying differences between the variables affecting the plant and root growth. The control and grapeseed oil were at least 5 colonies per storage container. In figure 4, the control system, in the first trial, did not reach higher than 6 colonies. Even though it did not have any additives, the researcher did not hypothesize the vast number of algae grown. Although, the researcher did not measure the leaf and root growth gradually, it was noticeably clear from the beginning which system had the best growth. The limited light system's plants grew the best, with one of the tallest leaves and it had the greatest root progression. The hydrogen peroxide system did not grow as fast as the other plants. It had significantly smaller roots and the lettuce leaves were much shorter.

During the second trial, the researcher did more algae counts, for more effective information to rely on. The researcher started to count the algae colonies three times per bin. This gave more validity for each trial. Conducting more tests per trial, provided more information to show which additive worked better to prevent/reduce algae growth and show which affect the plant's growth the most. The researcher hypothesized, the hydrogen peroxide would still express the most progress with reducing algae colonies, but as shown in the figures the limited light did not rise above one colony. The hydrogen peroxide system also remained below one colony. The hydrogen peroxide, like in the first trial, reduced each lettuce plant's growth immensely. The longest root did not get longer than five inches and the smallest one was three inches. The leaf height was also smaller in this system. The tallest one at nine inches and the smallest at seven and a half inches. During the second trial, the grapeseed oil's numbers rose to about the same of the control, but it never went higher than the control system. If one looks at the qualitative data, the grapeseed oil looks greener in color from algae, but the quantitative data shows a significance difference. Although it did have a higher count that the others, the control system had the most. The hydrogen peroxide system also remained below 1 colony and it proved the researcher's initial hypothesis. The researcher also measured root growth and leaf growth. By doing this the researcher could see which additive would affect the plant's overall growth. The lettuce plants had varying data because the different treatments affected the lettuce differently. As seen in the last two figures, the overall plant and root growth was larger in the limited light. The control subject also had great leaf growth, but the roots were much shorter than the limited light, for the algae count was higher in this test.

The researcher initially hypothesized how hydrogen peroxide, grapeseed oil, and limited light exposure would affect algae growth in hydroponics systems. By testing these different additives, one can see which treatment worked with the greatest efficacy to inhibit algae growth and which one demonstrated the least efficacy. As the researcher thought, the hydrogen peroxide system worked very well in preventing algae growth. In figure 4, one can see it does not rise over 1 algae colony. It kept the water noticeably clear and stayed clear for every trial. Since oil does not mix with water, the algae gathered around the oil and floated at the top. It clung to the sides of the net cups, the sides of the bins, and the roots. The roots were then suffocating because they could not get enough oxygen from the water. The limited light system exhibited the highest level of algae growth prevention. In figure 4, one can see the significant difference between the other systems. It had an experimental average of 0.77 colonies per storage container. This treatment had the least algae present. Light plays a huge role with the populating of algae. The control and grapeseed systems did not have strong enough additives to fight off the continuous growth of another challenge, mildew. In figure 3, the progression of algae stays mostly in a straight line. It showed little to almost no growth throughout the entire experiment. Even though, initially, the researcher thought the hydrogen peroxide may have been too harsh on the plants and the grapeseed oil would not have been strong enough from algae prevention, they were shown wrong. The hydrogen peroxide was not harsh on the plants grown in that system and they were shown that the grapeseed oil was not strong enough to prevent algae growth.

In addition to the first hypothesis, the researcher thought the lettuce plants would not have been affected by the additives enough to make a significant difference. The average results showed that algae growth was best controlled by the following variables respectively: limited light (.77 colonies per quadrant (CPQ)), hydrogen peroxide (1.22 CPQ), grapeseed oil (5.08 CPQ), and the control (5.92 CPQ). Plant growth measured as follows: limited light (13.6 inches (in)), control (13.15 in), grapeseed oil (7.35 in), and hydrogen peroxide (8.25 in). Root growth reflected from highest to lowest: limited light (11.3 in), control (9.25 in), grapeseed oil (7.5 in), and hydrogen peroxide (3.3 in). The hypothesis for the experiment was not supported. The researcher concluded that when considering all research questions (algae prevention, plant growth, and root growth), the most effective and efficient algae prevention plan is the use of limited light followed by grapeseed oil, the control, and hydrogen peroxide being last. Although hydrogen peroxide did prevent algae, the researcher determined it was detrimental to plant and root growth.

During this experiment, the different additives affected each plant uniquely. As seen in figure 1, the different practices affected each root length differently. Hydrogen peroxide was effective at killing algae. The limited light trial showed the best growth. Since the limited light had very few algae colonies, the leaves were able to get enough nutrition and oxygen. They were also large because as the sun shone on them, no algae bloomed because the bin was opaque. This system did not have to fight off any algae because of the treatments added to the box. In figure 2, one can see the differences between the growth of the hydrogen peroxide trial plants and the limited light system trial. The hydrogen peroxide had an average of 8.25 for the leaves, but the limited light leaves measured 13.6. Although the hydrogen peroxide system did not have the shortest leaves, the chemicals added still stunted its growth. If one looks at image 1, it can be seen how small the leaves are. Even though that was the beginning of the first trial, that system was smaller than the rest. The grapeseed oil additive did not do much to help or disturb the plant’s growing. However, it collected many algae, but since the additive was not harmful, it did not stunt the growth of the plants. One can see in figure 2 that there are only four columns in the grapeseed category. That is because one of the plants barely grew. The data was disregarded from the overall average and not included in the figures. Even though hydrogen peroxide helped limit algae growth, the researcher would recommend using limited light exposure because it was a heathier alternative for plant growth.

The final hypothesis made during this project was, how does grapeseed oil, hydrogen peroxide, and limited light exposure affect root growth. Once again, the researcher was not expecting any of the treatments to be too harsh for the plants. They were shown that the limited light was the safest and healthiest way to prevent algae and continue growing the lettuce carefully. The limited light had the longest roots, as seen in image 8 and figure 1. The qualitative and quantitative data show that this process was the best for hydroponically growing lettuce. The roots of the control system were one of the longest measurements. That was because there were no extra additives. Unlike the limited light system, there was a substation number of algae colonies in the water and along the roots. The roots were only 9.25 inches for the control system, but the limited light exposure roots were 11.3 inches. The roots were much longer in the limited light system compared to the other three systems. The grapeseed oil system had longer roots than those of hydrogen peroxide, but because there was an immense number of algae they did not get as long. In image 5, one can see how much algae were suffocating the roots. This made it harder for the plants to gain nutrients, thus resulting in one of the plants dying. Since grapeseed oil is an organic method, it was not potent enough to kill off mildew colonies. These different methods of preventing algae all showed significant differences in the root growth of the lettuce plants.

During this research and experimentation, the researcher had to switch up a few things. Initially, the researcher was going to use a harsh chemical to reduce algae growth, but they had to do some more research to see why that was a bad idea. The chemical would have killed the plants and made it unsafe for consumption. Also, the researcher, wishes they could have taken more algae counts. If they were to do it again, counting the algae every week from the beginning would be a priority. Doing this would provide more data and the information shown would have more reliability. It also would have shown more growth over the entire project, instead of just being the end of the first trial and then the second. Another thing the researcher would have completed differently is to conduct more trials. Conducting a third and maybe a fourth trial would have shown more data and given more accounts of which treatment worked better against algae populating. As seen in figures 1 and 2, there is data to support which treatment affected the plant and root growth the most, but the researcher did not start measuring the progress until later. If this project was completed again or an extension project was completed, the researcher would have taken more data from the root lengths and leaf heights, to see which additive reduced the size the most. If this project were to be redone, these changes would be implemented immediately.

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References

Cooseman, J. J. Control of Algae in Hydroponics Systems. *ISHS.* Retrieved from https://www.actahort.org/books/382/382_30.htm

Mattson, N. (n.d.). Testing Container Media. Retrieved from http://www.css.cornell.edu/courses/260/Media%20testing.pdf

Meireles Caixeta V. (2018) Hydrogen Peroxide for Insect and Algae Control in a Lettuce Hydroponic Environment. Retrieved from https://pdfs.semanticscholar.org/50e2/31736c67b26be49073423e3550f92ab4453e.pdf

Shrestha A. and Dunn B. (2010) Hydroponics. Retrieved from https://shareok.org/bitstream/handle/11244/50283/oksd_hla_6442_2010-03.pdf?sequence=1

Stephens, O. (2019). How to Get Rid of Algae in Hydroponics for Good! *The Hydroponics Planet.* Retrieved from https://thehydroponicsplanet.com/how-to-get-rid-of-algae-in-hydroponics-for-good/#:~:text=Algae%20can%20cause%20major%20problems,a%20system%20to%20its%20knees.

Teodora C. and Espiritu K. (2019) History of Hydroponics: When Was Hydroponics Invented? *Epic Gardening.* Retrieved fromhttps://www.epicgardening.com/history-of-hydroponics/#:~:text=The%20earliest%20modern%20reference%20to%20hydroponics%

20%28last%20100,solution%20of%20nutrients%20and%20water%20instead%20of%20soil.

Treftz C. and Omaye S. (2016) Hydroponics: potential for augmenting sustainable food production in non-arable regions. *Emerald Insight.* Retrieved from https://www.emerald.com/insight/content/doi/10.1108/NFS-10-2015-0118/full/html

Tripp, T. (2014). Hydroponics Advantages and Disadvantages: Pros and Cons of Having a Hydroponic Garden. Retrieved from https://books.google.com/books?hl=en&lr=&id=CYPoCwAAQBAJ&oi=fnd&pg=PT3&dq=issues+with+algae+in+hydroponics&ots=oOyJmyTx1E&sig=B48Gny8GStdkyHVSb0UJJn7RXy0#v=onepage&q&f=false

Sensorex. (ND). 6 Types of Hydroponics Systems Explained. *Sensorex.* Retrieved from https://sensorex.com/blog/2019/10/29/hydroponic-systems-explained/#:~:text=6%20Types%20of%20Hydroponic%20Systems%20Explained.%201%201.,5%205.%20N.F.T.%20%28Nutrient%20Film%20Technology%29%20More%20items