JOURNAL OF
EMERGING INVESTIGATORS

Article

A Scientific Investigation of Alternative Growing Methods to Cultivate *Lactuca sativa*

Samuel Fishback[1], Susan Duncan[1]
[1] Meadow Park Middle School, Beaverton, Oregon

SUMMARY

Hydroponics is the process of planting seeds inside a solid growth medium instead of soil and providing them with nutrients that soil would normally provide. Aquaponics is a method of growing plants without soil, utilizing fish waste to fertilize plants. In this experiment, we compared both methods to observe if hydroponic nutrients and fish waste would produce plants with different heights when growing a widely cultivated vegetable like *Lactuca sativa*. Our hypothesis was that aquaponics would be a more efficient farming method in terms of growth per day and average height, since the method uses a natural fertilizer. The aquaponics system would simulate an open environment, helping the plants better adapt to the natural fertilizer provided by fish. At the beginning of the experiment, the plants in the aquaponics system were taller than those in the hydroponics system, but the hydroponics plants had a faster growth rate than aquaponics plants by the end of the experiment. However, the aquaponics system had a higher growth rate than the hydroponics system in the majority of the experimental timeframe, and had a higher average plant height. Therefore, the aquaponics system was a superior system to the hydroponics system, producing plants with better height by 0.4 centimeters on the final day, and higher average growth rate by 0.02329545455.

INTRODUCTION

Aquaponics and hydroponics are similar methods of growing plants, though it is unknown which method is superior in cultivating edible plants such as lettuce. Aquaponics and hydroponics are still not as heavily used as traditional farming methods like organic farming, multiple cropping, and other farming methods that rely more heavily on soil and land (1). Because of their unpopularity, not much is known about these alternative growing systems, and a majority of farmers do not know the advantages that aquaponics and hydroponics have to offer, including a lower water requirement, a shortened growing period, and indoor compatibility (1, 2). Despite the high cost of required resources to produce a large-scale aquaponic or hydroponic system, both systems are appealing alternatives for farmers with less access to material resources (1).

Aquaponics and hydroponics need 90% less water than regular soil systems to operate (2), and allow plants to potentially grow faster than the regular household soil-plant (1, 2). The plants and fish in an aquaponics system have a symbiotic relationship in which the fish provide droppings, which the plant filters from the top of the aquarium to absorb their nutrients (1). The fish are protected from ammonium and nitrite spikes by the plants converting nitrogenous waste to nitrates (1). Hydroponics systems have a similar arrangement to an aquaponics system, though the nutrients are supplied to the system by pouring hydroponic nutrients in the water instead of having fish in the reservoir (1). Problems from growing plants using soil outdoors such as temperature, insects, weeds, overwatering, and high physical labor are remedied through using hydroponic or aquaponic systems (1).

There are currently three prominent ways to grow plants using hydroponics and aquaponics (3). One of them is media-filled beds, a system that utilizes a grow bed and a reservoir, with a pump bringing the nutrient-filled water to the plants in the growth bed (3). Another is the nutrient film technique, a system with plant roots hanging down through holes in a PVC pipe. A reservoir holds the nutrient-filled water with hydroponic nutrients or aquaponic waste from fish, which is pumped through the pipe. The pumped nutrients allows the plant roots to absorb all of the nutrients directly from the flow of water (3). The last system is deep water culture, a system that relies on having a styrofoam raft on top of a reservoir and plant roots hanging down from the raft into the reservoir to easily absorb nutrients. This system is also known as the raft system and is predominantly used for growing small plants (4).This experiment was suited for the raft system, as it is specialized in growing small plants like lettuce. Based on the experiences of teachers and students at Terra Nova School of Science and Sustainability, goldfish would accompany the aquaponics system because they produce a higher amount of waste than the average fish.

We hypothesized that the aquaponics system would be superior to the hydroponics system because the aquaponics system contains fish, producing a natural source of fertilizer for the plant. We propose that the lettuce will prefer a natural fertilizer like fish waste instead of an artificial one made by humans, which the plant would have to adapt to in order to grow since it's not a natural organic process. The cells inside the lettuce plant will be able to use the natural fertilizer with ease, meaning that cell replication will be faster when the plants are in an environment that simulates those of a wild lettuce plant

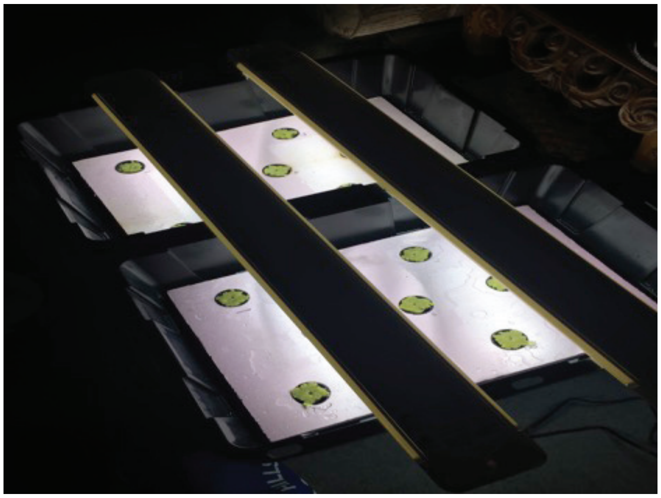

Figure 1: Picture of experimental setup on the first day. *L. sativa* seeds planted inside rockwool within a Styrofoam raft. Net pots contained LECA stones inside of raft systems with LED lights shining on both systems

near a body of water populated by fish. Existing literature provides comparisons between hydroponics or aquaponics to traditional farming methods that utilize nutrients from the soil, but not with each other. Therefore, this experiment was conducted in order to increase knowledge of comparisons of aquaponics and hydroponics performance.

RESULTS

This experiment was conducted to compare hydroponics to aquaponics. The data was collected through measuring the *L. sativa* plants inside both systems every day. Both systems had a black, plastic, reservoir holding water with a Styrofoam raft carrying the plants inside, along with LED lights to ensure the plants could photosynthesize (**Figure 1**). The Styrofoam raft contained small holes where net pots were put in which contained rockwool and Lightweight Expanded Clay Aggregate (LECA) stones as a medium for the *L. sativa* plants. The net pots contained small holes to expose the roots of the plants for them to absorb the nutrients in the reservoir. Water was then squirted in small amounts on each seed to initiate germination. Water was added to the reservoirs every week so that the water in each reservoir didn't completely evaporate. Comparing side by side observations and measurements showed which system (hydroponic or aquaponic) would produce a higher yield of a small plant such as *L. sativa*.

With the height data gathered over two weeks, the mean and growth rate were calculated for all the plants inside both systems for each day the experiment was conducted. The mean showed that the aquaponics system had a higher average plant height by 0.4 centimeters after two weeks (**Figure 5**). The aquaponics system had a slightly higher average growth rate of 0.2528409091, while the hydroponics system had an average growth rate of 0.2295454545 by the end of the experiment (**Figure 6**). The aquaponics system

Figure 2: Picture of the inside of the aquaponics system. The system contained three Carassius auratus with brightly colored pebbles on the floor of the reservoir.

also had a standard deviation of 1.283035635, while the hydroponics system had a standard deviation of 1.20896502

The aquaponics system had a higher average plant height, and a higher average growth rate during days 3 through 13 (**Figure 5**, **Figure 6**). The aquaponics system yielded higher plant height averages (**Figure 5**), but the hydroponics system had a higher growth average on day 14 (**Figure 6**), the same day that the hydroponic nutrients were

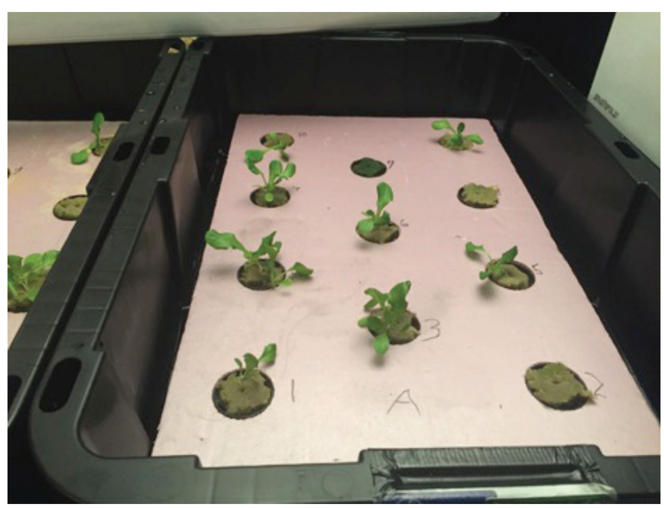

Figure 3: Picture of the aquaponics system on the eighth day with a Styrofoam raft and 11 plants inside contained in rockwool. Plants 2, 8, and 9 contained defective seeds. LED lights were removed for better photography and easier conducting of plant measurements.

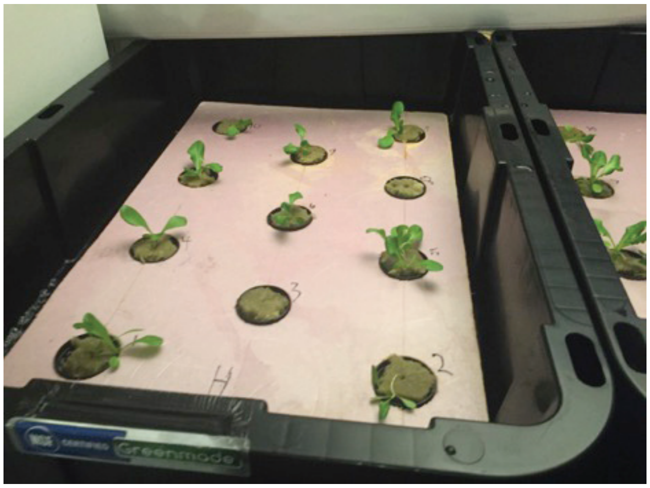

Figure 4: Picture of the hydroponics system on the eighth day. LED lights were momentarily turned off to enable better photography and easier plant measurements. Plants 3 and 8 contained defective seeds.

added to the hydroponics system before measuring plant heights.

DISCUSSION

Given our results in which the average plant height in the aquaponics system was higher than in the hydroponics system, our experiment supported our hypothesis. We hypothesized that the lettuce plants in the aquaponics system would grow quicker due to the aquaponics simulating a natural environment and because the hydroponics system had nutrients the lettuce plants might have to adapt to. The data supported the claim that the hydroponics plants adapted to the hydroponics nutrients slower than the aquaponics system, and then treated the nutrients the same way an aquaponics plant would treat fish waste after adapting. The hydroponics plants have better growth rates once they have adapted to their environment, unlike aquaponics plants which adapt immediately (**Figure 6**). We believe it's because of how their environment is simulated to be the same as a wild, natural lettuce plant near a body of water populated with fish.

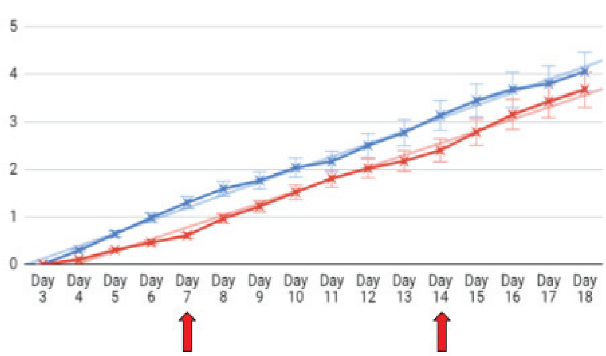

Figure 5: Graph of the average height from the 11 plants in each aquaponics and hydroponics system over time with trendline. R-squared values represent the distance from the trendline to the original graph. Error bars represent standard deviation of the plant heights.

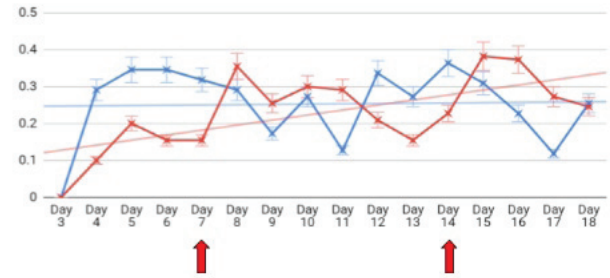

Figure 6: Graph of the average growth rate in centimeters of 11 plants in each aquaponics and hydroponics system on each day when conducting the experiment, along with error bars and a trendline with the R-squared value

While the experiment ended early in the lettuce plant's life cycle, that data can be used to determine their future height. If the plants continued to follow their pattern in height until their harvest, our conclusion of aquaponics as a better growth method wouldn't change.

The aquaponics system is superior to the hydroponics system, as the aquaponics system has a sustained higher growth rate through day 1 and day 13 (**Figure 6**) and had a higher plant height average (**Figure 5**). Therefore, the aquaponics system was better than the hydroponics system in plant height and growth, determining that the superior method of fertilization for plants is aquaponics.

Although our results suggest that the aquaponics system is the faster method for growing lettuce, there are still a few factors we have to take into consideration. For example, goldfish produce more waste than other fish. Using the same system with an alternative fish that is compatible with human consumption but produces less waste might change the results. If the experiment were longer, it would be possible that the hydroponics system could surpass the aquaponics system in height, using a trendline to predict the future average growth rate.

Not everything in the procedures went as smoothly as possible, and some human error may have affected the plant growth in both the hydroponics and aquaponics systems. For example, the amount of nutrients given to the hydroponics system could vary. The plants may have had too few nutrients for the hydroponics system to grow to expected sizes because the reservoir was larger than the one used in a previous experiment. We gave the same amount of nutrients that were used previously on the first week (one teaspoon), meaning the fertilizer was diluted in a larger volume of water. Another data fault was the living quarters of the three goldfish. Because of the use of a raft system, the plant roots were exposed into the reservoir. The roots tempted the fish to nibble at them, stunting the plant growth of the aquaponics system, and could have caused the growth rate of the aquaponics system to be lower than the hydroponics system at day 14 (**Figure 6**).

Aquaponics and hydroponics are systems that can grow plants of varying sizes and testing each plant out to see which system it is suited for is important. Using this experimental template, future research on these systems of plant and fish could include: growing different plants, and most importantly, seeing the types of phenomena that can emerge. For example, of the three main systems described in the introduction for aquaponics and hydroponics, we only studied one type of system, one type of fish, and one type of plant in this experiment. There are hundreds of combinations to experiment and discover what systems would be most optimal for all circumstances, and all combinations can be turned into further experimentation.

MATERIALS AND METHODS

Design and construction of a reusable fuel cell frame

A goldfish requires at least 19 liters of water to survive, so to make the system successful, a reservoir that could carry 75 liters of water would be required. Holes were drilled into a Styrofoam raft that was placed on the surface of the water inside the reservoir. Net pots were placed inside the holes. Lightweight Expanded Clay Aggregate (LECA) stones and rockwool were put inside the net pots of the reservoir which contained seeds. The previous steps were repeated to build the hydroponics system using an identical reservoir, Styrofoam raft with drilled holes, and net pots with solid substrate. Eleven seeds were planted in each styrofoam raft inside both systems, then a drop of water was squirted on each seed. Three goldfish were placed inside one of the filled reservoirs to create the aquaponics system. A teaspoon of hydroponic nutrients were added to the hydroponics system every seven days. Two LED lights were set above and shared between the two reservoirs to ensure that both systems had an equal amount of light. The amount of water added to both reservoirs each week was 3.8 liters. Every day, the three goldfish residing in the reservoir were fed as much as they could eat for two to three minutes using standard fish flakes that contained the proper nutrients for goldfish.

The height of the *L. sativa* plants were measured with a ruler in centimeters, and the data were logged using a data management tool that calculated the average mean and growth rate of all plants in both systems. Any of the plants that did not grow in the experiment were given a value of zero in all data and graphs.

ACKNOWLEDGMENTS

When going through this scientific investigation of finding an alternative sustainable food source, some special persons helped contribute. I would like to thank my peers in my science class for supporting my goals and helping edit my article to meet professional standards; my teacher, for assisting me by providing ample time, research, encouragement, and experts on the subject to help aid my investigation; the group of experts, including the wonderful students and teachers at Terra Nova School of Science and Sustainability, who helped me tremendously by providing me with information that I could use for both aquaponics and hydroponics. Finally, I would like to thank my parents, for providing all of the different materials that I couldn't get my hands on, and giving me all of the love and support that I could ever need when attempting to reach my goals.

Received: July 19, 2019
Accepted: April 14, 2020
Published: April 23, 2020

REFERENCES

1. "What Is Aquaponics?" *The Aquaponic Source*, 20 Oct. 2018, www.theaquaponicsource.com/what-is-aquaponics/.
2. Profita, Cassandra. "Aquaponics: Growing Fish And Plants Without Soil." OPB, Oregon Public Broadcasting, 2 Mar. 2012, www.opb.org/news/blog/ecotrope/aquaponics-growing-fish-and-plants-without-soil/.
3. "Types of Systems." *Backyard Aquaponics*, www.backyardaquaponics.com/guide-to-aquaponics/running-of-the-system/. Accessed 16 Nov. 2018.
4. D'anna, Christina. "Hydroponic Gardens: The Lettuce Raft Method." *The Spruce*, 30 Jan. 2019, www.thespruce.com/hydroponic-gardens-the-lettuce-raft-method-1939221.
5. "Alaskan town experiments with hydroponics as fresh food source." *Newsela*, 15 Nov. 2016, newsela.com/read/arctic-farming/id/24020/.
6. Bernstein, Sylvia, and Wilson Lenard. "Aquaponic Gardening Rules of Thumb." *The Aquaponic Source*, www.theaquaponicsource.com/aquaponic-gardening-rules-of-thumb/. 2018.