# THE INFLUENCE OF FISH TO AN AQUAPONICS SYSTEM


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# The influence of fish to an aquaponics system

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## Abstract

In an aquaponics system, nutrient-rich water from raising fish provides a natural fertilizer for plants. Aquaponics is a method to grow food in a sustainable way in an urbanized area, year-round and in every climate. Aquaponics can be used for indoor and outdoor farming, when there is a lot of space or a limit of it. This makes aquaponics a perfect method for the future to grow food regardless of the size of the space.

Our team tested an aquaponics system inside our school.
We were trying to prove that vegetables will grow faster and thrive more in water that is habited by animals like fish. The principal method of the aquaponics system is that the feces of the fish will act as nutrients for plants. Bacteria break down the fish feces and make it into particles plants can use to grow, to flower and to produce fruits or vegetables.
We had to rebuild our system three times in total to test the influence of different biological and non-biological factors that have impacted the system. We also had to make some small changes to assure all variables would be the same and the results would be as accurate as possible.

**Keywords:** every climate, sustainable, every scale, year-round, solution food shortage.

## Introduction to aquaponics

Aquaponics is a system where fish, bacteria and plants work together in a circulation to produce food in a sustainable way without damaging the climate. In the system the fishes excrete waste will be converted into nutrients by bacteria, the nutrients will be absorbed from the water by the plants. The water will have a better quality for the fish to live in, Due to the removal plants will be able to use the nutrients to grow. Because of the sustainable way of farming, this system is a perfect solution for the growing food shortage and the climate changes [7]. It is a system which could be used in all environments. Because of the fact the temperature can be regulated, the system is a great solution for areas which have a food scarcity hence to the unfavorable climate. The US is one of the biggest participating countries in the idea of using aquaponics to produce food, company’s like Pentair Aquatic Eco-System and Nelson Pade already are producing on a very large scale. [8]

## The main goal of the research

The main goal of this research was to find out what the influence of fish were to an aquaponics system. To find the answer to this question we created 2 different tanks both included growing plants. In one of the tanks we added fish to see the effect they would have on water quality and the plants, in contrast to the tank without the fish. We measured the length of the plants and tested the quality of the water. Our hypothesis before doing the experiment was: There will be a better water quality in the tank containing the fish, because they will produce nutrient rich waste. Therefore, the plants in the tank with fish in it will grow harder and stay healthy longer. We also think the roots of the plants in the tank without fish will be longer because they have a harder job finding nutrients in the water and, therefore, will need more length to find everything they need to grow and stay healthy.

## Theory

There are some important variables which have a lot of influence to the system. The system works best when all these factors have the right concentration, temperature and intensity. Some important factors to the aquaponics system are:

<u>PH</u>
One of the most important water quality variables in aquaponics systems is: pH can range from 0 to 14, with values between 0 and 7 being acidic, 7 being neutral, and values between 7 and 14 being basic or alkaline. PH influences many other parameters, such as the ratio of toxic to non-toxic ammonia and the rate of nitrification on biofilters. It is important to maintain pH at levels that are acceptable to both fish and plants. The compromise that is optimal to all three components of an aquaponics system—fish, plants, and nitrifying bacteria—is a pH of 6.8 to 7.0. However maintaining pH within such a narrow window can be difficult. If the pH is maintained between 6.4 and 7.4 it will be tolerable to all three components of the system. [1]

<u>Temperature</u>
The warmer the water, the less oxygen can be held. Water temperature in aquaponics systems are influenced by what type of fish can be reared, vegetable growth and the performance of the biofilter. The key is to find a

temperature that falls within the acceptable range for all three components of the aquaponics system. Warm-water species such as goldfish, bass, catfish, and tilapia prefer temperatures ranging from 65 to 85°F (18,3-29,4°C). Vegetables grow best at temperatures ranging from 70 to 75°F (21,1-23,9°C), and biofilters (nitrifying bacteria) perform optimally at temperatures ranging from 77 to 86°F (25-30°C). [1]

Ammonia

Ammonia is excreted by fish. Ammonia can exist in two forms: un-ionized ($NH3$) and ionized($NH4+$). Un-ionized ammonia is extremely toxic to fish, whereas ionized ammonia is not except at extremely high levels. The ratio of $NH3$ to $NH4$ + in water at any given time will depend on the pH of the water and the temperature. At pH 7.0 or below, most ammonia (>95%) will be in the non-toxic form ($NH4$ +). Looking at the temperature there is more toxic $NH3$ present in warmer water than in cooler water. [1]

The role of ammonia in establishing a biofilter: the process of building a bacterial colony during the initial setup of an aquaponics system is known as bio- filter establishment, or cycling. Cycling is the essential first step in setting up an aquaponics system. Until a healthy community of nitrifying bacteria has been established, the cycle is not complete and it will not be possible to grow plants. The process involves the steady, constant introduction of a source of ammonia into the aquaponic unit which feeds the new bacterial colony and allows it to grow resulting in the creation of a biofilter. [1]

The phosphate

It was assumed that at $PO3-4$ concentrations would not limit plant growth. Phosphate does not directly harm fish but increases the growth of the plants which be fostered by high phosphate levels. It was assumed that without algae growth higher phosphate levels do not harm the fish. Studies with aquaponics also reported phosphate in water from intensive recirculating fish culture systems. Most aquaponic systems goal for phosphate concentrations between 10 and 20 mg/l for light feeders (vegetative crops) and between 20 and 40 mg/l for heavy feeders (tomatoes, cucumbers, etc.).
[2]

KH and GH

With increasing GH values, it may be necessary to circulate part of the water in the system with water with a lower GH, so that the GH value is the same everywhere in the water. The rather low KH could also be increased by circulating water, but also with the use of a buffer such as sodium bicarbonate. The carbonate hardness (KH) describes the buffering capacity of the water. This means that the pH is more stable in water with a higher KH. A KH range of 50-100 mg/l is recommended. The recommended value for general hardness (GH) in aquaculture ranges from 50 to 100 mg/l. General hardness (GH) is a measure of the concentration of divalent metal ions such as calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$) per volume of water. The higher the KH value, the more PH there is in the water. [2]

The light in an aquaponics system

UV light treatment (a combination of white, red and blue LED light which can be used in an aquaponics system) in recirculating aquaculture has been suggested to reduce the amount of pathogen in the water. Without adding any chemicals into the water, thus maintaining fish health and decreasing the need for water circulation. Use of UV treatment in aquaponics could be a valid method to produce vegetables with highly hygienic standards. LED lights are a good source of light energy because its intensity can be adjusted, it has a low operating temperature and a long life as well as it uses less energy than other lights. The advantages of LED lights are increasing emphasis on producing clean food, conserving the environment and effectively utilizing energy. LEDs of various colour combinations were used as light sources for growing plants, one of them is:
white, red and blue LED. The combination of white, blue and red LEDs lights had potential to improve growth of vegetables grown on aquaponic systems in greenhouse and plant factories. [2] [3]

Degree of distribution

A plant can perceive its neighbour by feeling with its leaves, which creates a real battle for sunlight between plants, so by knowing it surrounding the plant knows whether it must grow in order to win the competition. Until now it was thought that plants could only noticed its surroundings through the reflection of light on the leaves. however, by touching each other, the plants perceive their neighbours much earlier in the growth process. Plants that are close to each other also appear to emit less fragrances when they compete for light. [4]

Ammonium, Nitrite and Nitrate

Plants can absorb all three forms of nitrogen, but nitrate is the most available. Ammonia and nitrite are very toxic to fish. Therefore, the concentration should be kept below 1 mg / l. In aquaponics, the concentration of ammonium and nitrite is always between 0-1 mg / 1, so this is no problem for the plants or the fish.
In acidicconditions, the ammonia binds with the excess hydrogen ions (low pH means a high concentration of H +) and becomes less toxic. This ionized form becomes ammonium. However, under basic conditions (high pH, above 7) there are not enough hydrogen ions and the ammonia remains in its more toxic state and even low ammonia levels can be very stressful for the fish. The activity of nitrifying bacteria decreases dramatically with high ammonia levels. Ammonia can be used as an antibacterial agent and at levels higher than 4 mg / l it will inhibit and drastically reduce the effectiveness of the nitrifying bacteria. This can result in an exponentially worsening situation where the bacteria die, and the ammonia increases even more. [5]

Effects of a high nitrate concentration
Nitrite is toxic to fish. Like ammonia, we limit ourselves here to reduce the effects on water quality. A nitrite level that is too high will have little effect on the water, apart from the effect on the fish. If the level of nitrate in your system is above 150 mg/l, the roots of the plant can burn nutrients,, which could be detrimental to their health.[8] It is an indicator that the bacteria are not working properly because nitrite is normally immediately converted to nitrate. If this is too high, a water change is usually the only solution.

Nitrate is a much less toxic substance than the other forms it is the most accessible form of nitrogen for plants. Nitrate production is the goal within aquaponics. Fish can tolerate levels of up to 300 mg / L. High concentrations will have a negative effect on plants, leading to excessive vegetative growth and dangerous nitrate accumulation in leaves, which is dangerous to human health. It is recommended to keep the nitrate content at 5-150 mg / l and to replace water when levels get higher. [5]

# Method

Application
We started making a setup for our aquaponics system on August 22, 2019 in order to answer our main question; what is the influence of fish to an aquaponics system? For this, we created two aquaria, one aquarium (of 60 cm x 30 cm x 30 cm) was filled with tap water, the other aquarium (120 cm x 50 cm x 25 cm) was filled with water that also contained a harness catfish which ensured that nutrients were present in the water. Furthermore, we placed the same pump and lamp in both aquaria so the circumstances were the same.

First experiment
In our first experiment we grew tomato cuttings in both aquaria. We put those cuttings on a raft with holes in it so that the bottom/roots of the plants were in the water. In the biggest aquarium we put eight plants scattered over the water surface and in the other we put eight plants arranged on a smaller raft. Then we waited until we could make an observation.

(120 cm x 50 cm x 25 cm) (60 cm x 30 cm x 30 cm)

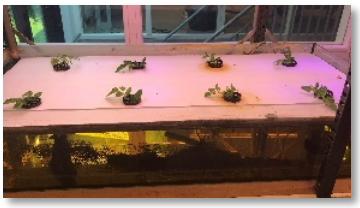


figure 1: bigger aquaria

figure 2: smaller aquaria

Keep track of changes
To keep up with the growth we made sure that we took a picture of both tanks every day. We took pictures of the roots of the plant and the plant itself. We also kept track of the actual growth, we measured the length of all plants separately with a ruler every two days. In addition to the measurements of the growth of our plants, we also monitored the water values. This included the pH, KH, GH, NH3, NO2, NO3 and PO4, we have graphed this data.

Imperfections
Soon, we discovered that something was not right with our setup: we had not taken into account various factor such as the two different sizes of the tanks being able to influence the results. Therefore, the value we observed was not realistic and we decided to change our setup and to restart over. We put new tomato cuttings in the rafts and waited to see how the plants would continue to grow. Over time we encountered a new problem: the fish ate the roots of our plants. Thus, we had to come up with something to prevent the fish from eating the roots. This is how we came up with the idea of putting chicken wire around the roots of the plants. To prevent inequality we also did this in the aquarium without fish. This meant that we had to start the experiment over for the third time.

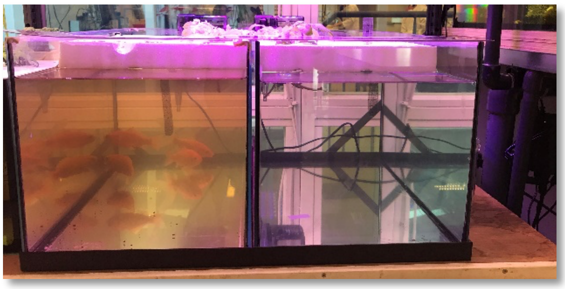


Figure 2: Aquaria without chicken wire

Figure 3: Aquaria with chicken wire

Visiting 'Duurzame kost'
On January 21, 2020 we went to visit a large-scaled aquaponics system in Eindhoven,
Duurzame kost (sustainable fare). On this trip we could see how an aquaponics system works on a large scale.
They use a system that uses less water than gardening in open ground because the water is recirculated, only the water that the plants absorb (or the water that evaporates) must be topped up. Moreover, it is not dependent on fertile soil. Fish provides a safe and healthy source of protein. In addition, this system does not use

large, environmentally polluting agricultural machines nor substances that are used are harmful to fish or plants.
The special thing about this system is that it was placed in the middle of the city. Therefore, this could be a great way of growing plants in the future in bigger, more densely populated places with a higher demand for food.

Figure 15: visiting an aquaponics system

# Results

Index:
- aquarium with fish
- Aquarium without fish

<u>Water values</u>

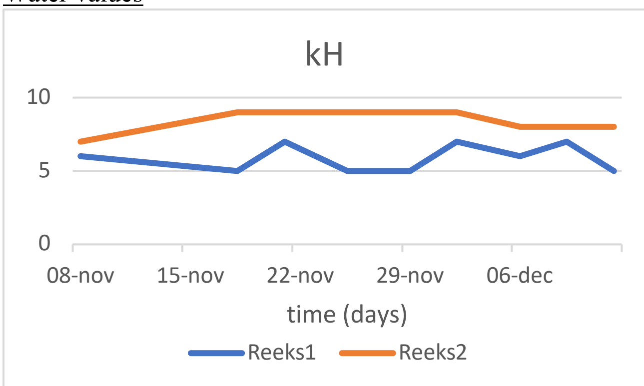



Figure 4: kH water values

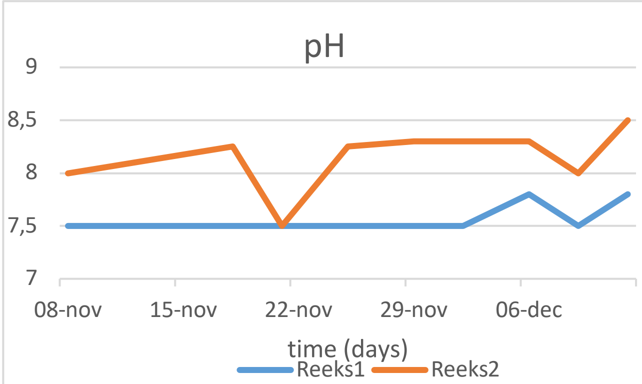



Figure 5: pH water values

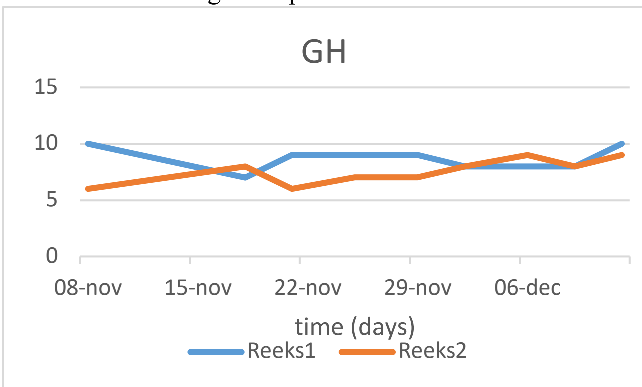



Figure 6: GH water values

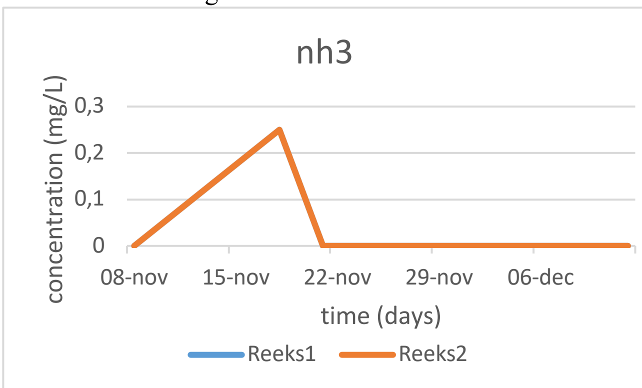



Figure 7: nh3 water values

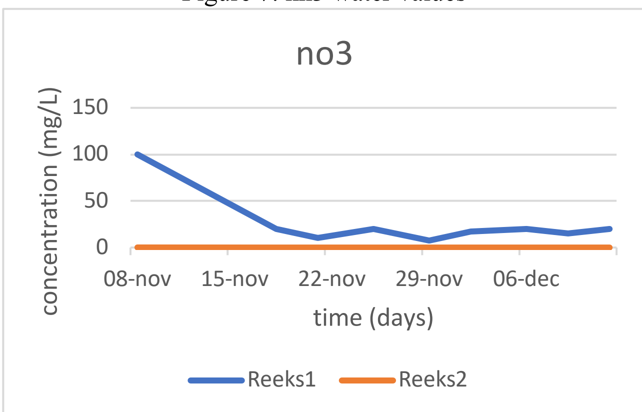



Figure 8: no3 water values

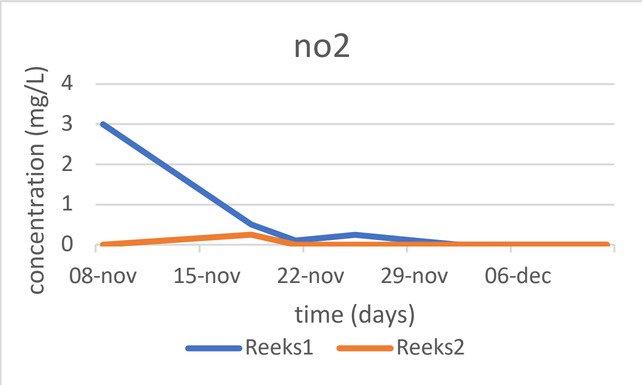



Figure 9: no2 water values

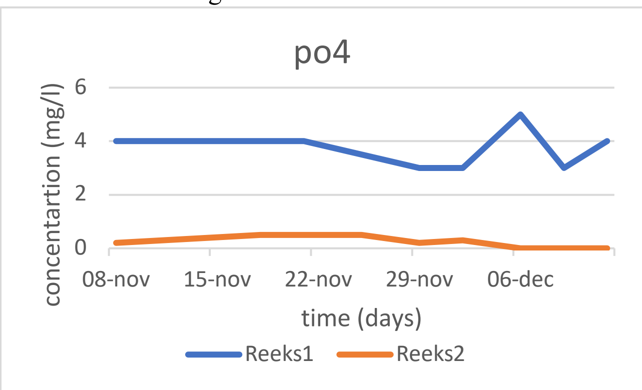



Figure 10: po4 water values

Plant growth

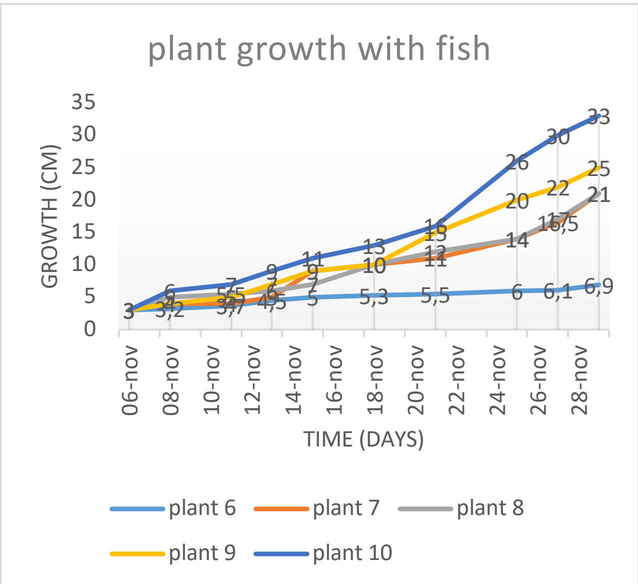



figure 11: plant growth without fish

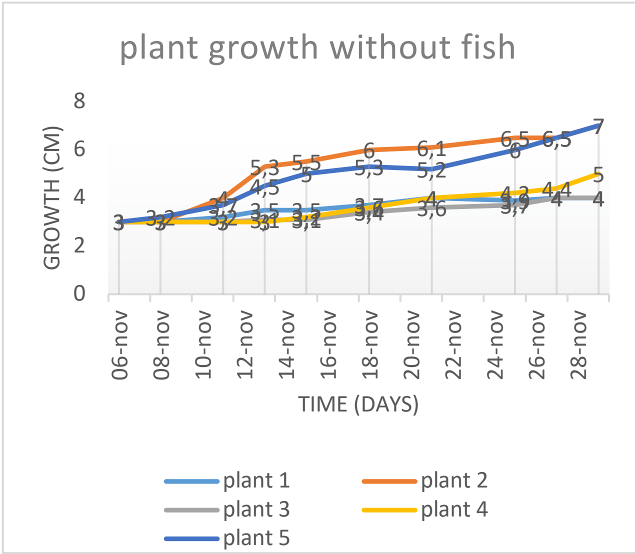



figure 12: plant growth with fish

# Conclusion

Hypotheses

Our hypotheses was: There will be a better water quality in the tank containing the fish, because they will produce nutrient rich waste. Therefore, the plants in the tank with fish in it will grow harder and stay healthy longer. We also think the roots of the plants in the tank without fish will be longer because they have a harder job finding nutrients in the water and, therefore, will need more length to find everything they need to grow and stay healthy.

Conclusion

We saw the water quality of the tank containing fish was significantly better for plant growth than the tank without fish. however, the roots of the tank containing fish were longer than measured in the thank without fish. Concluding we can confirm half of our hypothesis was correct.

Nutrients

The graph shows that there is a relatively high level of phosphate in the water that the fish swim in. The phosphate led to more algae growth in the container with fish, this was not harmful for the fish or plants.

You can see that the value of GH is relatively the same in both situations, which is also true because fish do not necessarily have an influence on this. And when fish have no influence on the GH in the water, and otherwise there is no difference between the two tanks with and without fish, the GH will be the same.

A high concentration of nitrite is very toxic to fish and therefore there should be little in the water with fish. In the beginning there is relatively much nitrite in the water of the fish and less in the water without fish. But once the fish and plants are in the water a bit longer, the nitrite in the container slowly disappears because the plants absorb the nitrite and use it to grow. The relatively high level of nitrite in the beginning caused the fish to make a kind of " antibody " against it, therefor it was not harmful for them.

It is visible in the graphs that with a decrease in no3, the growth of plants increases. This clearly has to do with plants that take up no3 and use it to grow. So, with more uptake of n03 there is an upward trend in the growth of plants.

You can see that the water without fish has a high KH. The reason for this is when the need of the plants for CO2 is higher than the supply, the CO2 source from the carbonate will be used and the KH value will drop. When the water contains fish, the fish absorb CO2, which means less CO2 for the plants, so the water with fish has a lower KH. This can be explained because the higher the KH value, the more PH there is in the water, and it appears that in the water without fish there is a higher PH than in the water with fish.

Growth

Looking at the results our conclusion contains that fish have a positive influence on the system. Our plants stayed healthy a lot longer than the ones without the fish and they grew a lot higher. The average length of the aquarium with fish the stems 21,38 cm. the one without fish was 5,4 cm. That is a difference of 15,98 cm.

figure 13: difference in length

Health

In the aquarium without the fish the plants showed having some nutritional deficiency. After 2 weeks brown stains started to form on the leaves which showed us they had a lack of nutrients. After comparing the theory and our water values (of the water without the fish), we realized that the reason for these brown spots was the lack of phosphate in the water. The ideal concentration of phosphate in water is between 20 and 40 mg/l, but our concentration stayed

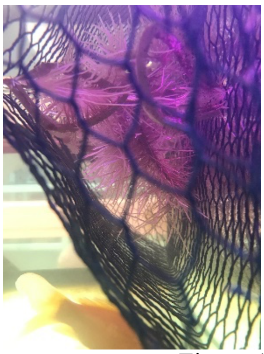
around 5 mg/l and below which resulted in an unideal growing environment for the plants which led to the brown spots.

Figure 14: brown spots on leaves

Roots

After 2 weeks a big difference was showing between the roots in the aquarium with and without fish. The first couple of days our assumption where correct, the roots of aquarium without fish grew a lot harder than the roots in the aquarium with fish. The plant in the aquarium without fish where having a harder job finding nutrients. Hence, they were growing longer to find the nutrients they needed. Over a longer period (two weeks) this switched because the aquarium with fish had more nutrients so the plants could grow harder. Because these plants were bigger, they continued needing more nutrients. Due to this the roots needed to grow longer to get all the nutrients they needed.

Roots is aquarium with fish



roots in aquarium without fish

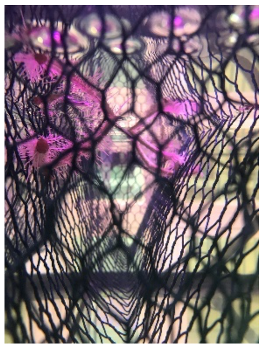


Figure 15: Roots after 2 weeks

## Discussion

After having done all the research we discovered some small problems:

- We had not considered the various factors, for example, the contents of the aquaria were uneven, the aquaria did not receive the same amount of light and the distance between the plants was uneven. We took the number of variables into account; we made sure that both tanks correspond to each other in terms of light, the content of the aquaria (both 60 cm x 30 cm x 30 cm) and the density so only difference between the aquaria was that there was one of the two with filled with fish (we also used a different type fish in the following experiments: 4 goldfish).
- We only did the right experiment once, for more accuracy we could have done the experiment several times, would have had resulted in a more accurate outcome.
- We could have looked at different kinds of fish. We only used the goldfish. If we observed the influence of other fish to our aquaponics system, we could have seen whether the plants would react differently in terms of growth and water values.
- The place we put our setup: we placed our setup in a public area which means that other people could influence our experiment. If we had placed it in an area with less chance of human interference it would improve the accurateness.
- During the experiment our fish began with eating the roots, for this we put chicken wire around the roots, which could have influenced the growth of the roots.
- We could have also taken more varieties into account such as the food we gave our fish.
- The fish could not eat the food we gave them because it was too big which is why we chopped it into pieces.

All in all, there were some accuracy points that we could have paid more attention to.

## Acknowledgement

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