Bachelor's project

NTNU
Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Biological Sciences Ålesund

Astrid Kristine Tennøy

# Utilizing Waste Products from Land-Based Aquaculture as a Source of Nutrients for Plant Growth in a System with Nutrient Film Technique.

Bachelor's project in Biomarine Innovation
Supervisor: Lars Gansel and Stig Tuene
August 2020

NTNU
Norwegian University of
Science and Technology

Astrid Kristine Tennøy

# Utilizing Waste Products from Land-Based Aquaculture as a Source of Nutrients for Plant Growth in a System with Nutrient Film Technique.

Bachelor's project in Biomarine Innovation
Supervisor: Lars Gansel and Stig Tuene
August 2020

Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Biological Sciences Ålesund

NTNU
Norwegian University of
Science and Technology

# Summary

Agricultural land and fresh water are increasingly scarce resources. New sustainable ways of food production need to be explored, to secure food for the rising world population. Combining aquaculture in the form of sludge from land-based fish production with hydroponics, is a way of recycling valuable resources that would otherwise be deposited or end up at sea.

This research experimented on how the common tomato plant 'Balkonzauber' and the salt tolerant halophyte 'New Zealand Spinach' grew in different water treatments. Plants were separated into different growth mediums: hydroponic solution and waste product from a Norwegian salmon hatchery at different salinities (0ppt, 5ppt and 13ppt). A soil treatment was added to see difference between hydroponic and soil growth, when irrigated with waste product and 13ppt. This to see if plants could grow on nutrients from waste products, and which treatment would provide the highest growth rate.

Plants grew better in hydroponic solution and soil. For tomato plants a high growth was seen in fresh water with waste product. New Zealand spinach did not perform well in any hydroponic treatment with waste products as nutrients. The low growth was surprising as the species is a halophyte. Particles stuck on roots, seem to limit water and nutrient uptake. Other limiting factors could be linked to temperatures, salinity and waste product nutrient compositions. Further research needs to be completed to optimize growing conditions.

There is future potential in growing vegetables in waste products from aquaculture, but to achieve this more research must be done. Connection the system to a land-based facility and start a larger-scaled experiment would be the next step.

## Sammendrag

Jordbruksland og ferskvann er stadig mer begrensede ressurser. Nye, bærekraftige metoder for matproduksjon må utforskes for å sikre mat til den voksende verdensbefolkningen. Ved å kombinere akvakultur i form av slam fra landbasert fiskeproduksjon med hydroponikk plantevekst, kan man resirkulere verdifulle ressurser som ellers ville gått tapt.

Prosjektet så på hvordan tomatplanten 'Balkonzauber' og salttolerante halofytten 'New Zealand Spinach' vokste i forskjellige vannbehandlinger. Planter ble separert i paralleller med forskjellige vekstmedier: hydroponisk løsning og slam fra et settefiskanlegg, med forskjellige saltholdigheter (0ppt, 5ppt og 13ppt). Planter i jord ble også inkludert. Dette for å undersøke forskjeller i vekst mellom hydroponisk- og jordbaserte miljøer, for planter behandlet med slam og 13 ppt salt. Målet med prosjektet var å se om plantene kunne vokse på næring fra slammet, og å se hvilken behandling som ga høyest vekstrate.

Plantene vokste bedre i hydroponisk løsning og i jord. Tomatplanter hadde en høy vekst i ferskvann med slam, men ikke i salt. New Zealand-spinat presterte dårlig i hydroponiske behandlingene med slam som næring. Den lave veksten var overraskende ettersom arten er en halofytt. Partikler på røttene så ut til å begrense opptak av vann og næringsstoffer. Andre begrensende faktorer kan være knyttet til temperaturer, saltholdighet og næringsstoffer fra slammet. Ytterligere undersøkelser må utføres for å optimalisere vekstforholdene.

Det er potensiale i å dyrke grønnsaker i salt slam fra landbasert oppdrett, men for å oppnå dette må det forskes mer på området. Det neste trinnet er å koble systemet til et landbasert anlegg og starte et større eksperiment.

# Acknowledgements

This bachelor was supposed to be about marine aquaponics with the species Litopenaeus Vannamei and New Zealand spinach. The research was to be carried out at 'Laboratorio de Moluscos Marinhos' at the Federal University of Santa Catarina (UFSC) in Brazil. Due to Covid-19 the experiment was cancelled, right before the experiment was to begin. All students abroad were ordered home from their exchanges. This led to big changes in the thesis and increased time pressure. It was therefore decided to use waste products instead of living species. This to be able to carry out an experiment from home and also make it more relevant for the Norwegian aquaculture industry. Because of the pandemic it was difficult to complete necessary water analysis and get a hold of proper measurement instruments, which have limited the quality of the research.

A big thanks to my family for helping out with practical issues throughout the experiment. I'm also grateful to my counselors Lars Christian Gansel and Stig Tuene, for all help through valuable advice and support. I wish to thank fellow students at the UFSC for giving important inputs on how to build and perform the experiment. Special thanks to Elaine Ferenhof for all support and knowledge on New Zealand spinach.

# Table of Contents

# Figures



# Tables

# 1. Introduction

## *1.1 Background*

The population of the world is constantly growing and currently (January 2020) there are more than 7.7 billion people on the earth (3). The UN has estimated that the world population will reach 9.8 billion in 2050 (4). To support this rise in population food production needs to be increased by 70 to 100 percent (5). The need for more sustainable ways to produce food is rising to maintain an elevated production rate.

Another big challenge for global food and water supply is the freshwater resources in the world. The number of people affected by water scarcity is predicted to rise rapidly, as the population continues to grow (6). Even though there are 1400 million cubic km of water in the world, only 0.003% of these are freshwater resources (7). The Food and Agriculture Organization of the United Nations states: *"On average, agriculture accounts for 70 percent of global freshwater withdrawals."* (7). For these reasons, we need to change towards more sustainable water usage to increase agriculture production, or even just to maintain today's production rate.

Around 50% of the total habitable land on the earth is used for agriculture (8). This puts strains on the environment in forms of climate change, pollution, deforestation and a general degrading of the environment (9). The last 20 years there has been a decrease in agricultural land (10). Agriculture cannot be significantly increased in a sustainable way, but there are vast areas for aquaculture along the coasts (10) (11) (12).

## *1.2 Aquaculture*

Aquaculture is breeding, rearing and harvesting of fish and other species from a controlled marine or freshwater environment (13). Aquaculture facilities range from small scale producers to big international companies. It is a industry with high-tech equipment and constant innovation (14). Figure 1 shows the rapid growth of aquaculture production.

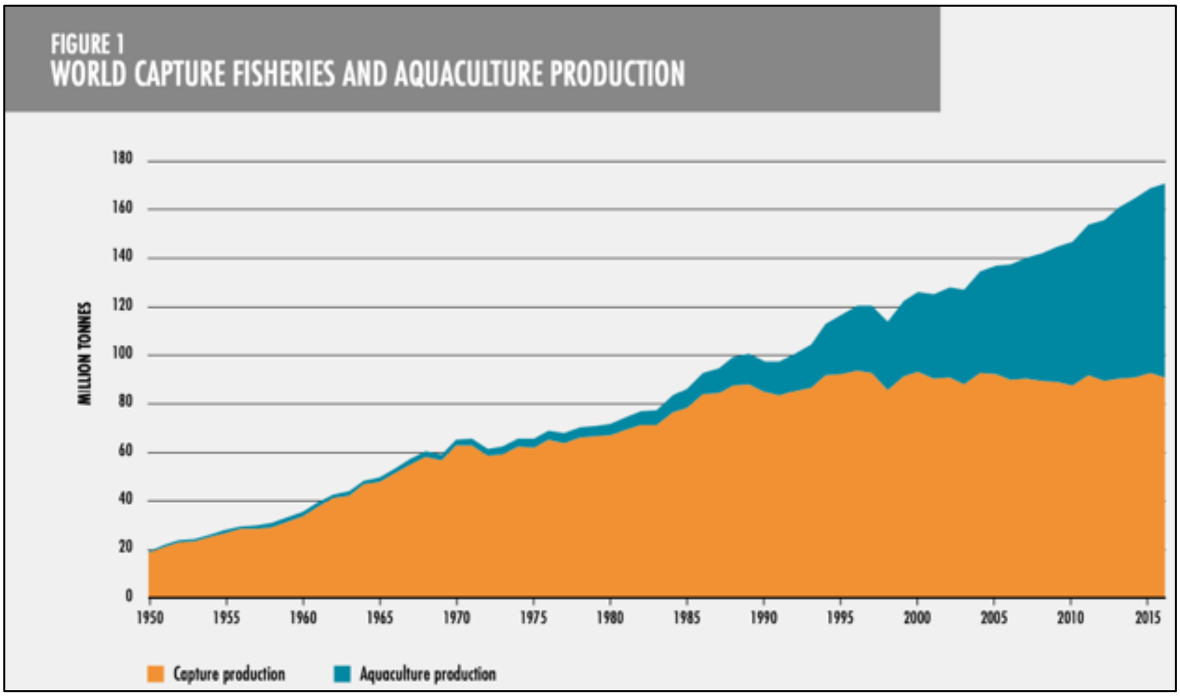



*Figure 1 Growth of fisheries and aquaculture (12).*

Since 1990 the aquaculture industry has grown with approximately 7.8 percent each year (15). Growing protein like salmon through aquaculture, is the most sustainable approach to farming of animal protein. It also creates the lowest carbon footprint (15) (16).

The number of land-based aquaculture facilities are increasing all around the world. Land-based systems provides complete control over production and water quality (17). Modern facilities recycle water through RAS systems and uses significantly less water. The system may be utilized at locations far from sea and large fresh water sources. This provides opportunities for countries without sufficient coastlines, to still produce through aquaculture (18). Waste products from land-based systems are solid waste, $CO_2$ and ammonium (19). NIBIO states that each year 27.000 tons of nitrogen and 9000 tons of phosphorus ends up in the ocean due to land-based aquaculture in Norway. Large amounts of solids are collected, yet significant quantities of dissolved nutrients are released to nature. Research show that nitrogen and phosphorus mainly follow the waste water, but a small part remains in the dried waste product (20, 21). New facilities being built in Norway today are under requirements to collect waste products (22). Producers have to pay to dispose these waste products (23), which means that this is a considerable resource that need to be further utilized.

Even though most land-based productions are done in freshwater (12), fish waste from productions using salter water can also be utilized. This would be highly relevant for Norwegian production where the first phase of salmon farming is done in freshwater, and later phases are in brackish and saline water. As the salmon is an anadrome species it smoltifies. This means that a physiological change takes place within the fish, preparing it to go from freshwater to saline water (24). Thus, the salinity in the waste product from a hatchery facility will change during the salmon's life cycle. More post-smolt is anticipated to be grown to a bigger or even full size in land-based facilities or semi-closed and closed cages at sea. Land-based production of other species is also expected to rise (25). Resulting in higher amount of waste products. This gives opportunities to recycle nutrients that would otherwise end up at sea, like the limited sources of phosphorus (26).

Waste products are being tested as fertilizers in agricultural fields to see if valuable resources can be recycled (26). The Norwegian company 'Høst' applies waste products in fertilizer sold to Vietnam, which show promise in increasing growth for farmers (27). As agricultural land is limited (8), other methods for food production should be considered. FAO states that: *«In the future, aquaculture and aquaponics may play a greater role in coping with the increased demand of a growing world population»* (28). The increasingly popular method of aquaponics can be used to recycle resources (29).

Aquaponics is a method of combining aquaculture with hydroponics. Non soil methods have shown efficient growth, takes up less land and provides endless opportunities in modifications (30). For example, it can be built as vertical farms in cities (31). By combining land-based aquaculture with plant production in such a way, one can efficiently utilize resources and thereby create less waste (32). To understand what aquaponics is, the method of hydroponics is first introduced.

### *1.3 Hydroponics*

Hydroponics is the concept where plants are grown without the use of soil. There are many different methods within hydroponics, but in general the roots of the plants will be floating in nutrient rich water (33). Nutrients are added through specialized nutrients solutions providing everything the plants need to grow (34). The root system can either be free in the water or supported by other mediums like perlite, clay pellets or rockwool. This allows for a more efficient nutrient uptake and in many cases faster growth, with an increased production of 30 percent (33).

### *1.4 Aquaponics*

Aquaponics is a combination of recirculating aquaculture and hydroponic growing of plants, in a system that continually recycles water. This method is based on biological processes that occurs naturally, including nitrification (35) (36).

To give a further understanding of how aquaponics work, Figure 2 shows the process of a simple nutrient film technique system (NFT). The system works by fish eating fish feed and producing ammonia. This ammonia is discharged through the gills (37). As the plants cannot use the ammonia they depend on nitrifying bacteria to transform the ammonia to nitrate, which plants can utilize for growth (38). Nitrifying bacteria are found in the hydroponic part of the system, in the gravel or on the root system of the plants. As plants use the nitrates as nutrients, they remove it from the water and clean water can be returned to the fish tank (36).

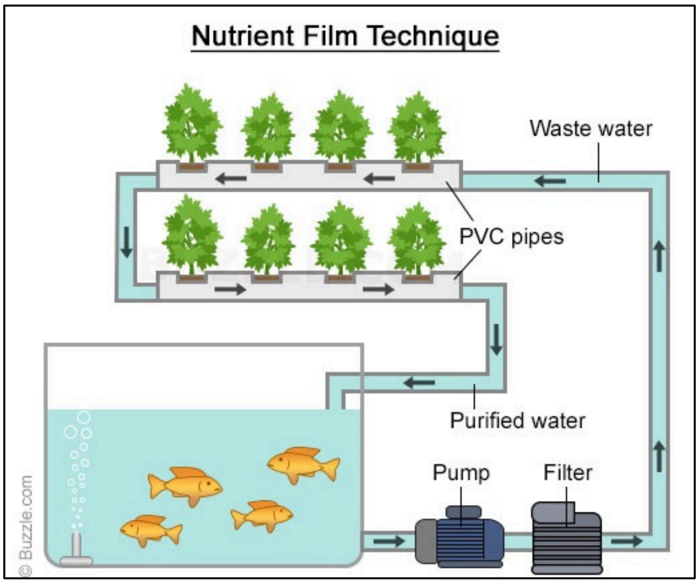



*Figure 2 Explanation of an NFT aquaponics system (1).*

Aquaponics systems can be built and customized in a variety of ways (Appx. 1). Compared to traditional agriculture, there are many advantages of growing plants and proteins together in an aquaponics system; less use of freshwater and electricity, more efficient growth of plants, less pests and therefore less use of pesticides, less waste products that can affect the environment and no fish escapes (29).

Most of today's aquaponics production is based on freshwater systems. Lotus student organization successfully tested the combination of hatching facility with freshwater aquaponics (39). However, there are land-based facilities utilizing saline water, such as those of salmon farming. Using the waste products in combination with marine aquaponics is therefore a possibility. The biggest difference between regular aquaponics and marine aquaponics is the fact that it uses saline water and therefore a different set of species. This is not practiced at a large scale yet, but mostly by researchers who are testing its potential. A combination of marine fish or crustaceans together with plants with a high tolerance of salinity, has been proven to work by several researchers (40) (41) (2).

### *1.5 Halophytes*

Most plants will die if irrigated with seawater, but there is a group of plants that can thrive and grow in such conditions. These plants are called halophytes and they are naturally specialized with mechanisms that allows them to survive conditions with high salinity and arid climate (42) (43).

"*The emergence of seawater-irrigated vegetables is a milestone for the development of the seawater-irrigated agriculture in the world.*" (44). As there is a shortage of fresh water in the world, many researchers are looking at seawater agriculture, with halophytes and seawater-irrigation, as a means for food production. Up to 15% of underdeveloped land around the world's coastal and inland salt deserts could be used for growing crops with the method of saltwater agriculture (45).

Plants known to do well in marine aquaponics are Sea Purslane, Saltwort, Salsola, Sea Asparagus and New Zealand spinach (Appx. 2) (40) (41) (46). New Zealand spinach is an halophyte and has also proven to do well in hydroponics (46). Experience with this plant was recently gained through exchange studies at Federal University of Santa Catarina. Tomato and basil have proved to grow significantly in solutions with 4g salt/liter (47). Tomato plants are often used in freshwater aquaponics system. It would therefore be interesting to see if the plant could grow in a more saline aquaponics system.

### *1.6 Focus of the Research*

The aim of this research was to examine an alternative way of using waste products from aquaculture in combination with hydroponic growth of plants. This to explore a sustainable way of food production in a world with rising food and water scarcity. In addition to recycling valuable nutrients.

The problem statement was *"Can valuable resources from land-based aquaculture be utilized as nutrients for plants grown in hydroponic systems, to provide a sustainable way of food production?"*.

The original idea was to conduct a marine aquaponics system with shrimps and New Zealand Spinach at the UFSC in Brazil. When this was not possible, the focus changed, and the shrimps swapped with waste products. A hydroponic system was made to simulate an aquaponics and can at later stages be connect directly to a land-based facility. This could therefore be seen as the first part of a learning process on marine aquaponics and how to build a system. Time was limited and plants did not reach full size during the experiment. Low cost materials had to be used, as money for the project was limited.

Thus, this work examined how the tomato plant 'Balkonzauber' and the halophyte 'New Zealand' spinach grew in an NFT hydroponic system at different salinities, with waste products from a salmon hatchery facility as nutrients. The hypothesis being tested was:

1. There will be a difference in growth between plants grown in hydroponic solution and in waste product.
    a. The parallel with hydroponic solution will provide the best result in growth
    b. Waste product as nutrients will provide as good a growth as the hydroponic solution.
2. Plants in hydroponic pipes will grow better than soil parallels.
3. There will be a difference in growth between plants grown in different salinities.
    a. Tomato plants grows best at low salinities and dies in high salinities.
    b. New Zealand spinach grows best at the highest salinity.
    c. New Zealand spinach grows better than tomato plants at higher salinities.

The term "parallel" or "P" is used throughout the thesis and refers to groups of similar plants grown under the same conditions with the same growth medium.

# 2. Material and methods

This thesis used an experimental approach to research and gain more understanding about the problem statement. A quantitative approach was used to find primary data on growth of plants in different water setups. All growth tests were conducted from 28.04.2020 to 26.05.2020.

Materials used to gain data in this research were biological materials such as waste product and plants, and structural materials for the build of the system.

## *2.1 Biological Materials*

### *2.1.1 Waste Product from Salmon Farming*

Dried fish waste used in the experiment was obtained from a Mowi salmon hatchery in Steinsvik, Norway. The waste material was supposed to be analyzed at NTNU laboratories. Due to Covid-19, the laboratory at NTNU was not open during the period of this experiment. The waste product had previously been analyzed by Eurofins, dated 2017 (Appx. 3). The experiment solemnly relied on this analyze regarding the specific waste product used.

The dried waste product used for the project was treated in systems from Sterner AS. On their web page they state that the fish sludge is rich in nitrogen and works well on plants. In addition, they state that 90% is dry matter, and it contains zinc and phosphorus (48). NIBIO reports that the main problems with fish waste as fertilizer are high levels of cadmium, zinc and arsenic. These elements should be monitored and kept at a safe level (26).

### *2.1.2 Tomato Plants*

'Balkonzauber' *(Solanum lycopersicum)* is a small bush growing tomato plant which is moderately sensitive to salinity (49). It is a typical salad tomato and the plant does not grow too large, it was therefore suitable for an NFT.

For tomato plants nitrogen, phosphorus and potassium are the main nutrients, but also calcium, magnesium and sulfur are necessary in smaller doses (50). Half or more of the total nitrogen should be added as nitrate-nitrogen ($NO_3$), to increase the yield (50). Zinc, boron, iron, molybdenum, chloride, copper and manganese are micronutrients that are essential to complete an array of different processes within the plants (51).

Requirements for nutrients change over time as the plants grows in different stages. A chart over nutrient sufficiency ranges in tomato plants can be seen in Figure 3.

| | N | P | K | Mg | Ca | S | Na | B | Zn | Mn | Fe | Cu | Al |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | | | | | | | ppm | | | | | |
| From | 3.00 | 0.30 | 2.5 | 0.5 | 2.00 | 0.5 | 0.01 | 40 | 35 | 100 | 100 | 8 | 20 |
| To | 6.00 | 0.80 | 5.00 | 1.00 | 6.00 | 0.9 | 0.01 | 60 | 50 | 200 | 200 | 20 | 200 |

*Figure 3 Nutrient sufficiency ranges in tomato plants (50).*

Figure 4 shows the change in uptake of five important nutrients throughout the life cycle of the tomato plant (50). Gonzales et.al. states (52) from their research that the seedlings of tomato plants were able to uptake the nutrients even in solutions with very low concentrations.

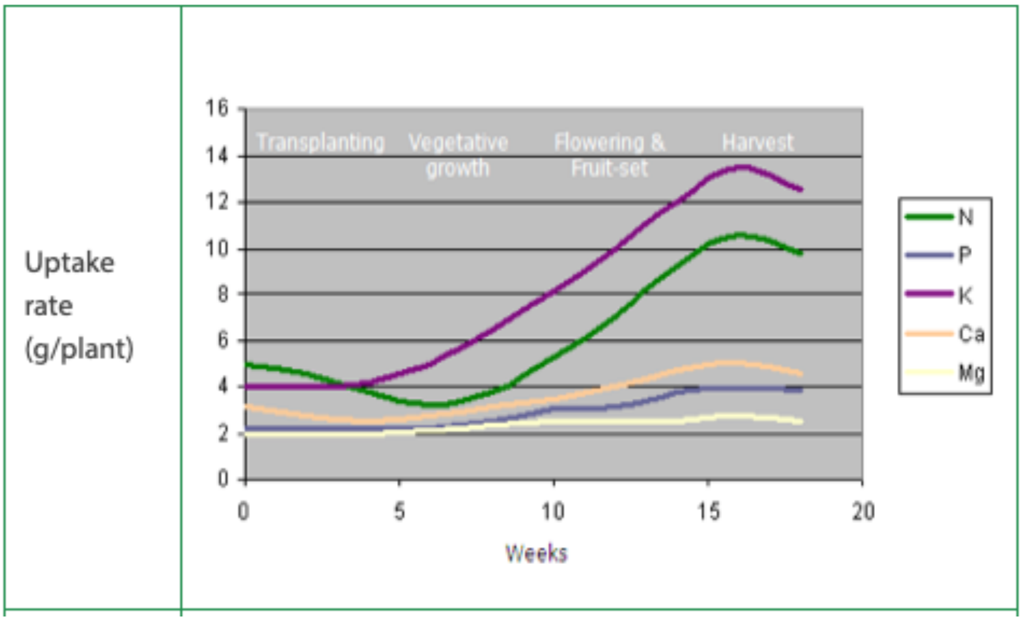



*Figure 4 Changes in nutrient uptake in the lifecycle of tomato plants (50).*

### *2.1.3 New Zealand Spinach*

Tetragonia tetragonoides, also known as New Zealand spinach or Warrigal greens, is a halophyte in the Aizoaceae family. This spinach substitute can tolerate harsh environments such as high salinities, drought and warm climate (53, 54). The species was chosen as it can grow in high salinities.

The benefits of this plant species are; potential for high biomass production, multiple harvests throughout the year and easy reproduction and crop management. In addition, it is easily accepted by the consumers because of its appearance as a leaf vegetable (54). The plant contains high levels of vitamin C, antioxidants and fibers, but also harmful oxalates (53) (54).

When doing research on the New Zealand Spinach nutrient requirements for the plant were difficult to find. Ahmed et. al. (55) researched effects of nitrate, calcium and NaCl on the Tetragonia Tetragonoides. Plants grown in smaller amounts of nitrate had fewer leaves and a significantly lower weight mass. Calcium had no effect on the growth, and salinity had a positive effect on plants grown in 100mM NaCl (55). Yousif used a special plant nutrient solution for New Zealand spinach (56). This was used as a base for nutrient calculations for the species (Appx. 4). As it is a halophyte the plant thrives in salt conditions. Information was obtained at the UFSC that the New Zealand spinach grows best at 13ppt (57). Tetragonia tetragonoides was therefore expected to grow well in hydroponics or aquaponics systems using more saline water.

Two very different species were chosen for the experiment. Tomato plants to show growth for a non-halophyte that grows fast and is widely used all over the world. New Zealand Spinach as an edible halophyte well suited for growth in combination with marine aquaponics. Both plants could be able to grow in systems with fresh water and moderate salinities, which would be the environments in a hatchery facility.

## 2.2 Timeline

The method for collection of data was carried out in different stages. Figure 5 show the timeline for the project.

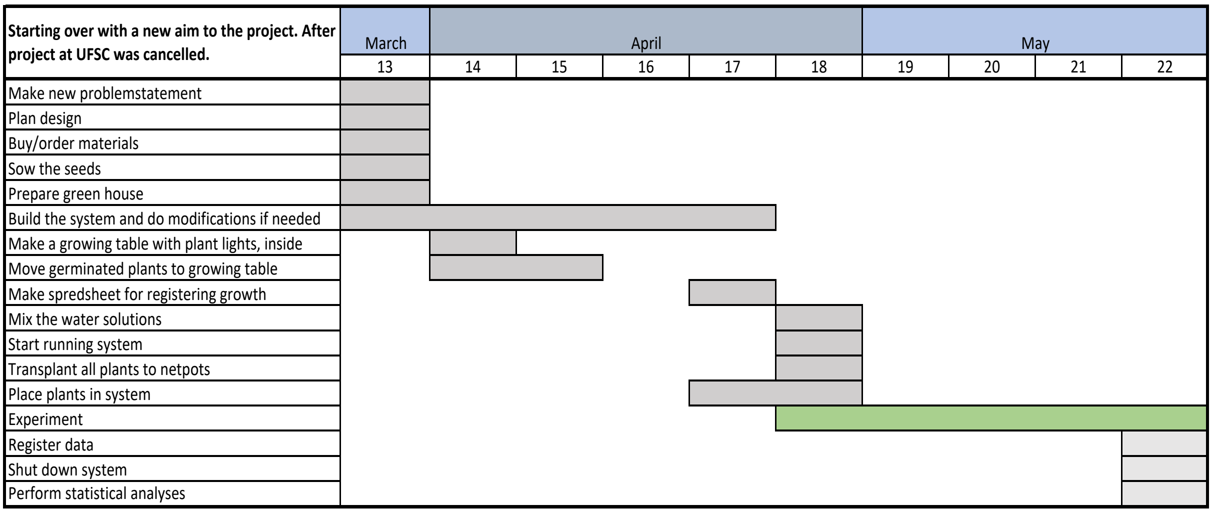



*Figure 5 Timeline for the project.*

## 2.3 Preparing start plants

Two plastic containers (6 liters) were drilled holes in, 2,5 cm over the bottom. Gravel were filled up to the holes to secure adequate drainage.

### 2.3.1 Tomato Plants

Tomato plants thrive in nutrient rich soil (51), 6 liters of vegetable soil were therefore used. 40 seeds were sown in the soil (457 seeds/m$^2$). 17 seeds were also sown in a smaller plastic container as a backup in case not all the seeds would germinate to plants. A temperature of 22°C was recommended for germination (58), actual temperature was 21°C.

### 2.3.2 New Zealand Spinach

New Zealand spinach in the wild grows in sandy soil. From conversations with master student Elaine Ferenhof at the Federal University of Santa Catarina, it was known that spinach thrive when grown in a mix of soil and sand in the ratio of 1:2 (59). The box was therefore filled with 2 liters soil mixed with 4 liters sand.

The plants had several seeds inside a capsule. To make them geminate capsules were placed in water for 24 hours (59, 60). 40 capsules were sown in the sandy mix (457 seeds/m$^2$). 17 were also sown in a plastic container as backup, similarly to the tomato seeds. A temperature of 15-25°C was recommended for germination (60) The actual temperature during germination was 21°C. After germination plants needed to be placed in sunlight, or under an adequate light source (60).

For both plant types the soil was watered with fresh water through a spray bottle. The germination containers where then covered in cling film to keep them humid. Containers were kept on a heated floor to get sufficient heat to germinate the seeds. The containers were checked on every day to see the growth and to make sure the soil was moist. After germination plants were moved to a cooler area (15-16°C). Development of start plants were documented in Figure 6 and 7. From the left: day of sowing, day 1, 5 and 17 after germination.

*Figure 6 Tomato plants after sowing.*

*Figure 7 New Zealand Spinach after sowing.*

### *2.3.3 Growing Lights*

As the plants were planted in late March in Norway, the sunlight from the windows were not adequate as a light source. The light intensity was increased from 50 LUX to around 5000 LUX, and then 16 000 LUX by adding three artificial plant lights and homemade reflectors. This light intensity was equivalent to daylight, but not direct sunlight (61). Tomato plants are high energy plants that needs at least 5000 LUX for growth. It was recommended to have a minimum of 20 000 LUX to grow a robust plant (62). Little information was available about the optimal light intensity for New Zealand spinach, other than it being a full light plant (60). It was therefore under the same conditions as the tomato plants (Fig. 8).

*Figure 8 Plants under artificial lights and reflectors.*

It should be noted that the maximum light intensity achieved during the growth phase was below the recommended light intensity for robust growth of high energy plants. However, 16 000 LUX are in the middle of the range of light intensities of full daylight (61). According to Digest (62), consistent growth is expected at this light intensity.

## 2.4 Building the Hydroponic System

To ensure that the design suited the set of hypothesizes being tested, a list of criteria for the structure were set (Appx. 5).

The system was set up by using a nutrient film technique (NFT). The principle of NFT is that roots are in a constant stream of nutrient rich water, in this case from the water containing waste product or hydroponic nutrient. The water flows in one direction with the help of gravity (29). An NFT system can be constructed as a small and light system that do not require big amounts of space or solids, like other systems (Appx. 1). Strengths of an NFT system are that plants can get the exact nutrients it requires for ultimate growth, the roots are sufficiently oxygenated and the risk of pests, fungal and bacterial infections is highly reduced (63).

There are some weaknesses with using an NFT system. Temperatures in a Norwegian greenhouse differ widely from day to day, and day to night. It will therefore not be possible to keep the nutrient film at a constant temperature, which might affect the plants. Bigger solid of fish waste could get stuck on the roots and block the oxygen supply. Malfunctions to the system can occur, like pump failure. This would leave the plants dry which could kill them (63).

### *2.4.1 Blueprints*

The blueprints were based on principles of aquaponics systems with NFT at the UFSC (2). Some modifications were made to fit the specific criteria of this experiment (Appx. 5). A detailed blueprint of the system was made (Fig. 9). Four individual parallels were set up, each parallel with one pipe for each species. In addition, an extra parallel with soil plants was made.

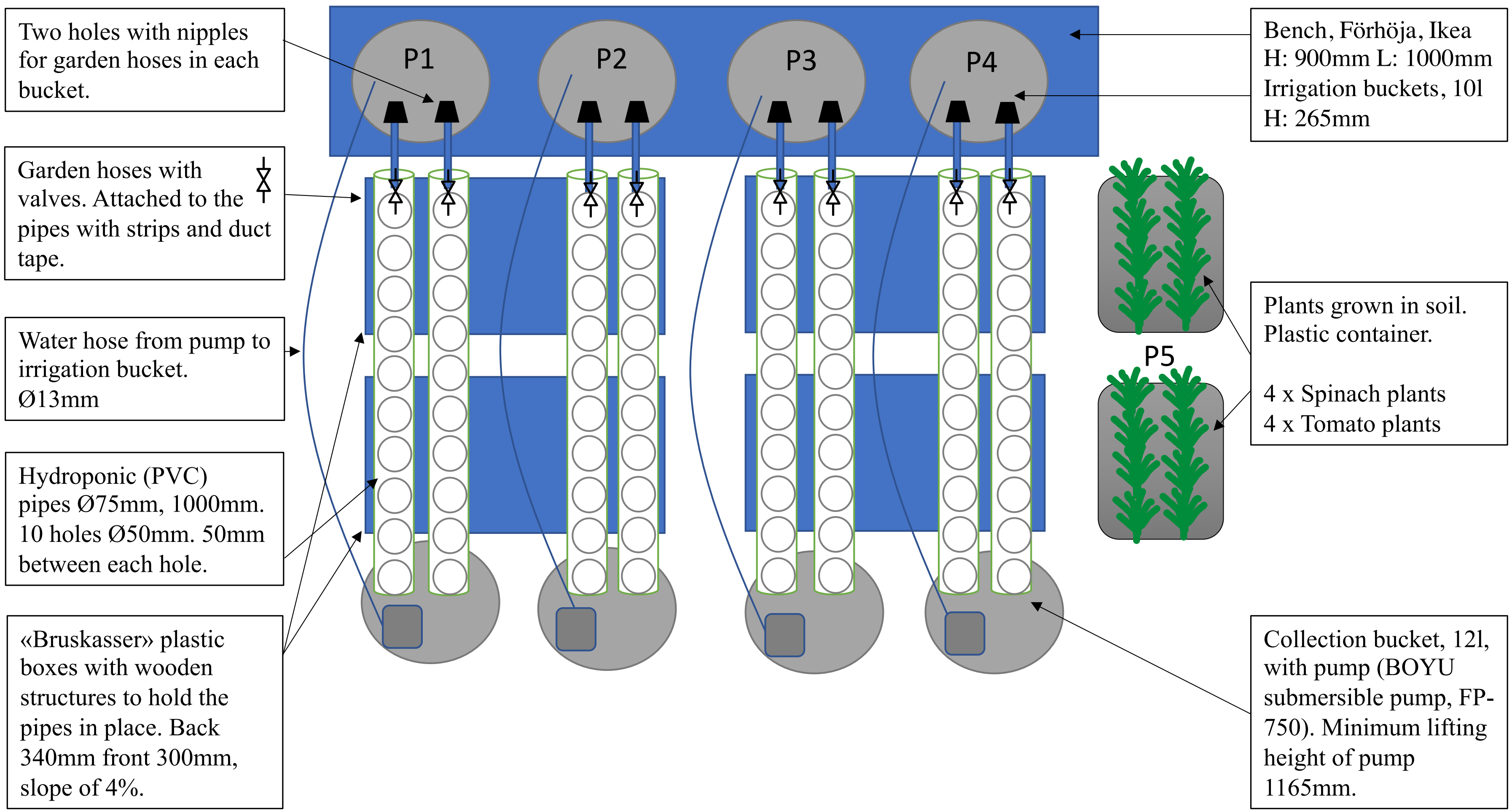



*Figure 9 Explained blueprint of the system.*

### *2.4.2 Material*

Mainly solid materials were chosen to build a stable and lasting system. The main structures were made from plastic and wood structures. Some cost-efficient material had to be chosen. See Appendix 6 for a full list of materials.

### *2.4.3 Building Process*

The structure was built based on the blueprints (Fig. 9). Eight PVC pipes were cut to 1000 mm length. Ten holes with 50 mm diameter were made in each pipe, with 50 mm distance between holes. Pipes were placed on top of the plastic container and held in place by a wooden structure with 4 half circles of 80 mm diameter. The structure in the back was 40 mm higher than in the front to achieve a slope of 4% (see eqn. 1). This to achieve an optimal flow rate as suggested by Pinheiro (2).

$$\frac{1000mm\ pipes}{100} * 4 = 40mm \tag{1}$$

All of the four parallels consisted of one bucket for irrigation water, two pipes and one bucket for water collection including a pump. The pump sent the water back up to the irrigation bucket, as illustrated in the blueprint. Water pumps with lifting height of 1500 mm and max water flow of 750L/h was used for the experiment (BOYU submersible pump, FP-750). This created a continuous stream of water. The irrigation bucket had two holes in the bottom that led the water out through garden hoses with valves at the ends. The valves were connected to the hydroponic pipes and regulated the water flow.

The system was set up in a greenhouse. Bubble wrapper was used to make a separate space, almost like a tent, inside the greenhouse. This to get a higher temperature for the plants, as temperatures during spring can vary widely (64). The system was started without plants to make sure everything worked according to plan. Pictures were taken during the building process (Appx. 7).

Net pots were placed in the holes on the hydroponic pipes. Because of problems connecting the valves and securing sufficient irrigation for the first plant, the first hole was left open and only 9 plants were used.

## 2.5 Experiment

### 2.5.1 The Irrigation Compositions and Calculation of Nutrients

Four different water parallels were prepared for the system. Table 1 gives an overview of why the different irrigation compositions were chosen for the system.

*Table 1 An overview of the different irrigation used in the system.*

| Parallels | Reason behind the composition |
|---|---|
| P1 - Hydroponic solution | Hydroponic solution (Hydroponisk näring, Nelson Garden) was used to see the best possible outcome. The solution contains a solution of inorganic material and mix ratio is 2ml/l. This made it possible to compare the other water parallels with a set of "control" plants (Appx. 8). |
| P2 - Fresh water with waste product | To resemble the wastewater from a salmon hatchery facility in the early phases of the salmon life cycle, before it is smoltified. |
| P3 - Waste product and 5 ppt salinity | To resemble the wastewater from a hatchery in the later phases of the salmon life cycle, during the smoltification process. |
| P4 & P5 – Waste product and 13 ppt salinity | To resemble the wastewater from a hatchery in the later phases of the salmon life cycle, during the smoltification process. |

The lifespan of a tomato plant is approximately 5 months (20 weeks) (65). Of these 20 weeks, the plants spent 4 weeks in the experiment. The plants double their weight in two weeks (66), giving approximately 5,5% daily growth. Tomato plants needed more nutrients than spinach, so the level of nutrients was customized mainly for tomato plants, and then hopefully the spinach utilized the nutrients it needed and not more. As the New Zealand spinach grows at the same period of the year as the tomato plant, it was assumed the lifespan was around 20 weeks as well. It was expected that tomato plants and spinach would grow respectively 500g and 400g per parallel during the trail. These numbers were calculated from the start weight with a daily growth rate of 5,5% for 28 days.

The two most significant nutrients for plants until flowering stage, are nitrogen and phosphorus (51). Tomato plants need 30-60g nitrogen per kg growth, for spinach the amount is 1g/kg. For phosphorus the numbers are 3-8g/kg and 0,11g/kg respectively (Appx. 9). Plants need for phosphorus would be covered when adding the amounts of waste product needed to secure a sufficient nitrogen level (see Appx. 3). Using 50g/kg as a combined need for nitrogen for both species, the amount of nutrients to add weekly and daily, was calculated (Tab. 2). It was assumed that not all nutrients would dissolve in the water. Carrying out a pilot trial and analyze the dissolved nutrients, was not possible due to Covid-19.

*Table 2 Calculations on fish waste to add daily and weekly.*

| Calculations on waste product to add to secure sufficient nitrogen levels for the plant | | |
|---|---|---|
| Content of N in tomato plants | 50 | g/kg |
| Total weight of 9 start plants | 20 | g |
| Average growth per day (5.5% daily growth gives appx. the double weight in two weeks) | 5,5 | % |
| Alternative: Growth per two weeks | 100 | % |
| Number of days from start until finish | 28 | days |
| | | |
| Days until next water change | 7 | |
| | | |
| Content of N in the waste product | 45 | g/kg |
| Added waste product at water change (once a week) | 15 | g |
| Added waste product (daily in addition to at water changes) | 10 | g |

To secure a steady stream of nutrients for plants to utilize, it was decided to have a surplus of nutrients in the water at all times (Tab. 3).

*Table 3 Calculations to secure a surplus of nutrients.*

| Calculations to secure sufficient levels of nitrogen (N) | | |
|---|---|---|
| Waste products are added once a week at water change, in addition to once daily. The remaining N is removed at water change. | | |
| | | |
| Total amount N utilized by plants | 3,5 | g |
| Total amount N added | 15,3 | g |
| Remaining N at the first water change (and N utilized by plants) [g] | 3,4 | 0,5 |
| Remaining N at the second water change (and N utilized by plants) [g] | 3,2 | 0,7 |
| Remaining N at the third water change (and N utilized by plants) [g] | 2,9 | 1,0 |
| Remaining N at the end of the experiment (and N utilized by plants) [g] | 2,4 | 1,4 |
| N added minus N utilized by plants | 11,8 | g |

For P1 mixing ratios according to the description for the hydroponic solution was used. Amount of nitrogen was similar for waste product and hydroponic solution as they contained 4,54% and 4% nitrogen (Appx. 3, 8, 9)

If too much nutrients were added the plants could suffer from nutrient burn. The nutrients replace the water uptake in the leaves, stopping water from reaching the entire leaf. This would appear as discoloration, with brown or dead areas on the tip of the leaves. This burn can also be seen in plants with perfect nutrient contents, then other factors such as temperature, light or diseases can be the reason (67).

### *2.5.2 Preparing Plants for Transplant*

Plants were carefully taken out of the soil. Roots were rinsed in water to remove excess soil. Roots were put through the holes in the bottom of the net pots to ensure that plants could reach the nutrient film. Then pots were filled with hydro granules. The hydro granules (leca) were cleaned and soaked in advance. Plants were then moved to the system as soon as they were ready (Fig. 10, 11 and 12).

*Figure 10 Extracting and measuring tomato plants.*

*Figure 11 Measurements and transplant of tomato plants.*

*Figure 12 Measurements and transplant of New Zealand Spinach*

### *2.5.3 Start Up*

The different parallels were prepared by measuring correct amount of waste product, salt or hydroponic solution as seen in Table 4. P1 solemnly consisted of 20 ml hydroponic solution mixed with fresh water. Fifteen grams of waste product was sieved for big solids and measured for P2, P3 and P4. Salt according to wanted salinity was dissolved in hot water.

*Table 4 Overview of amounts to add in the parallels at weekly water change.*

| Growth mediums | Hydroponic solution | 2. Fresh water + WP | 3. 5 ppt saltwater + WP | 4. 13 ppt saltwater + WP |
|---|---|---|---|---|
| Hydroponic solution (ml/10l fresh water) | 20 | 0 | 0 | 0 |
| Salt (g/10l fresh water) | 0 | 0 | 50 | 130 |
| Waste product (g/10l fresh water) | 0 | 15 | 15 | 15 |

Waste product (WP) was mixed with room temperature water to dissolve lumps (Fig. 13). Salt and waste product solutions were mixed together. Extra solution of P4 was made to irrigate soil plants in P5.


*Figure 13 Preparing water parallels with waste product and salt.*

Buckets were filled with water (9l) and placed at the end of the hydroponic pipes. Pumps were submerged, connected and system started running. Water flow was set and then the solutions (1l) were added (Fig. 13). The total amount of water in the system was 10l.

The system ran without plants to see if adjustments needed to be done. One observation was that parts of the fish waste particles settled at the bottom of the buckets, which could create a problem for the pumps.

The first two days all plants were kept in the same nutrient without changes. This was done to acclimatize the plants before adding more nutrients. From the third day of the experiment, 10 g waste product was added every day in P2, P3 and P4. The waste product was mixed in 200 ml water (Fig. 14). For P1, 5 ml hydroponic solution was added. Buckets were topped up with water if evaporation due to warm weather occurred.

*Figure 14 Procedure of mixing daily supplement of waste product.*

Weekly water changes followed the same procedures as the startup for the system, according to Table 4. In addition, buckets and pumps were rinsed before newly mixed water parallels were added.

### 2.5.4 Soil Plants

Soil plants were added to containers with the same soil mixtures as during germination. The plan was to have 9 plants of each species, but due to lack of material, 4 tomato plants and 4 spinach were used. Irrigation mix was made similarly as for P4 and plants were watered as needed. Approximately 1dl/plant two times a week.

### 2.5.5 Flowrate

Flow rate was adjusted to 1-2 liters per minute per pipe, as suggested by (68). As roots grew and impeded the water, the flow had to be monitored. The flow was controlled by timing how long filling a measuring cup (1l) took. This was done for each pipe and valves were adjusted accordingly.

*Figure 15 Roots and waterflow as water returns to collection buckets.*

### *2.5.6 Plants During Experiment*

In the first 9 days after transplant the state of the plants was documented daily through comments, temperatures and pictures (Appx. 10). After this, documentation was done twice a week.

After the transfer to the system both spinach and tomato plants were drooping and did not perform well. Two days after plants looked a bit better and seemed to recover. Some leaves died from the shock of the transplant. These were removed so growth of healthy parts would not be impaired. Two weeks into the experiment all tomato plants in P4 were dead and removed. 7 new tomato plants were put in the pipe. At the same time all tomato plants in P1 started developing flower buds.

As the laboratories at NTNU were closed, pH and salinity testers were not available. Salinity was therefore only calculated at water changes. The same was the case for temperature loggers, therefore temperature was measured manually, and inaccuracy could occur as temperatures during night hours were unknown.

Temperatures were kept between 13-25°C. An oven was used at night and colder days. Doors and windows were open during warmer days. Water temperatures varied, but attempts were made to keep it between 15-25°C. Light intensity at daytime ranged between 5000 and 70.000 LUX.

Leaks occurred in the connection point between pipe and valve. The plastic strips lead water out of the pipes. By turning the strips upwards, the problem was solved.
Slime on roots was removed mid-way through the experiment. Difference in root systems between hydroponic and waste product treatments can be seen in Figure 16.

*Figure 16 Clean roots (P1) and roots with slime (P2).*

### *2.5.7 Finishing Trial*

All plants were taken out of the system. Roots from neighboring plants were entangled and bigger roots were difficult to untwine. Leca was removed from pots and plants were taken out. Some net pots had to be cut open to get roots loose. Slime and water were removed as much as possible.

### *2.5.8 Registrations*

Before plants were placed in the system, measurements of height and weight were taken. Spinach plants weighed less than 1 g, and all 9 plants in each parallel were weighed together to avoid high relative measurement errors. Tomato plants were heavier and were weighed individually. The results were registered in an excel form (Tab. 5). Start weight, total height and root length was not measured for P5 as the plants remained in soil. The average start measurements of all other parallels were registered as start weight. Plants of close to equal size were randomly chosen for the different parallels. It is therefore likely plants in this parallel had a start weight similar to the others. Average and standard deviation was calculated. Same measurements were made and registered in the form at the end of the experiment. In addition, plant height was measured two weeks into the experiment.

*Table 5 Template of registration form.*

| | Parallels: | Plant number: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total | Average | Standard deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant 1 | 1 | Height total [mm] | | | | | | | | | | | | |
| | | Height upper part | | | | | | | | | | | | |
| | | Height roots[mm] | | | | | | | | | | | | |
| | | Weight [g] | | | | | | | | | | | | |
| | 2 | Height total [mm] | | | | | | | | | | | | |
| | | Height upper part | | | | | | | | | | | | |
| | | Height roots[mm] | | | | | | | | | | | | |
| | | Weight [g] | | | | | | | | | | | | |
| | 3 | Height total [mm] | | | | | | | | | | | | |
| | | Height upper part | | | | | | | | | | | | |
| | | Height roots[mm] | | | | | | | | | | | | |
| | | Weight [g] | | | | | | | | | | | | |
| | 4 | Height total [mm] | | | | | | | | | | | | |
| | | Height upper part | | | | | | | | | | | | |
| | | Height roots[mm] | | | | | | | | | | | | |
| | | Weight [g] | | | | | | | | | | | | |
| | 5 | Height total [mm] | | | | | | | | | | | | |
| | | Height upper part | | | | | | | | | | | | |
| | | Height roots[mm] | | | | | | | | | | | | |
| | | Weight [g] | | | | | | | | | | | | |

A registration form for visual observations was used to register numbers of branches and leaves (for spinach), color and general state of the plants (Tab. 6).

*Table 6 Template for registration of visual observations.*

| Visual check of plants | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant 1 | 1 | Branches: | | | | | | | | | | |
| | | Leaves: | | | | | | | | | | |
| | | Color: | | | | | | | | | | |
| | | State of plant: | | | | | | | | | | |
| | 2 | Branches: | | | | | | | | | | |
| | | Leaves: | | | | | | | | | | |
| | | Color: | | | | | | | | | | |
| | | State of plant: | | | | | | | | | | |
| | 3 | Branches: | | | | | | | | | | |
| | | Leaves: | | | | | | | | | | |
| | | Color: | | | | | | | | | | |
| | | State of plant: | | | | | | | | | | |
| | 4 | Branches: | | | | | | | | | | |
| | | Leaves: | | | | | | | | | | |
| | | Color: | | | | | | | | | | |
| | | State of plant: | | | | | | | | | | |
| | 5 | Branches: | | | | | | | | | | |
| | | Leaves: | | | | | | | | | | |
| | | Color: | | | | | | | | | | |
| | | State of plant: | | | | | | | | | | |

It should be noted that measuring spinach was difficult as it grows more horizontally. The best way to measure it was by weighing. This was not possible in the middle of the experiments as it would ruin plant roots when they were extruded from the net pots. Plants that died throughout the trail, before achieving any growth were registered as “x”. The template was adjusted to fit the needs for registrations throughout the experiment; start, mid, end and dry weight. All plants were measured by aerial and root length and weight. Plants were cut in two, separating the aerial part from the roots and parts were weight individually.

Plants were placed on baking trays and in the oven at 70°C. Different methods of drying plants can be found. Some researchers recommend drying them for a long period of time (24 hours) (69), while others state that 10 hours is sufficient (Carberry, 2020). Due to the situation (COVID-19), plants were dried in an private oven that had to be turned of at night. Plants were therefor dried for a relatively short period of time, with 10 hours as suggested by Carberry, 2020. Dry weight was measured to the accuracy of 0.001g using a Precisa 205 A SCS.

### 2.6 Statistical Analysis

The results of height, wet and dry weight were analyzed by one-way analysis of variance (ANOVA), using IBM SPSS statistics 26. This analysis is used to evaluate statistical significant differences between the means of one or several groups (70). In this case ANOVA was used to analyze statistically significant differences of growth in plants between five parallels. Analyses for tomato plants and New Zealand spinach are conducted separately. ANOVA cannot point out which groups that are statistically different, therefore a Post hoc test, Tukey, is included. The Tukey is used to determine statistically significant differences when more than two groups are analyzed. The significance level was 0.05 for all tests. P-values $<0.05$ means there is a statistically significant difference in means between the groups. P-values $>0.05$ means there is no statistically significant difference (70).

Means ($\overline{X}$) are calculated by:

$$\bar{x} = \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right) \tag{2}$$

Population standard deviation is calculated as:

$$\sigma = \sqrt{\frac{\Sigma(X-\mu)^2}{n}} \tag{3}$$

Average daily growth in gram is calculated with the growth rate formula:

$$\frac{(S2 - S1)}{T} = ADG \tag{4}$$

(71). S1 is start weight/height of plant, S2 is end weight/height and T is time. Time stand for the number of days between measurements, in this case 28 days.

# 3. Results

## *3.1 Tomato Plants*

All tomato plants in P1, P2, P3 and P5 survived the experiment. In P4 all plants died after a week. New plants were added in P4, these also withered, and results were not registered.

### *3.1.1 Plant Weight*

Expected growth for each parallel with tomato plants was 500 g and nutrients were calculated based on this growth (see page 23). The average growth in weight was registered at the start, mid and end of experiment (Fig. 17).

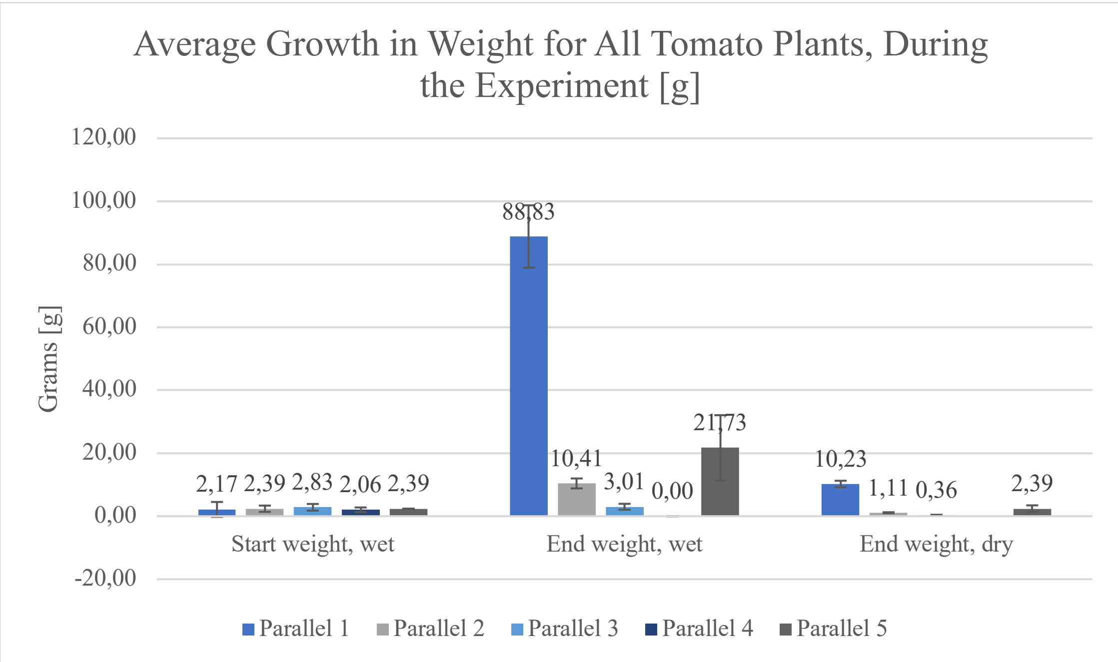



*Figure 17 Growth in weight for tomato plants at the start and end of the experiment.*

Start weights in all parallels were relatively similar, between 2.06 g (P4) and 2.39 g (P2 and P5) (Fig. 17). There was no statistically significant difference between any of the start weights ($F(4,35) = 0.949$, $p=0.447$). There was a statistically significant difference between P1 and all other parallels in end weights (wet and dry) ($P<<0.05$). While P2-P5 were statistically significant different from each other. ($P>>0.05$) (Tab. 7).

*Table 7 Tukey Post Hoc Test for Tomato plants.*

| Tomato plants | Parallel | Parallel2 | P - value |
|---|---|---|---|
| End weight | P1 | P2 | .000 |
| | | P3 | .000 |
| | | P4 | .000 |
| | | P5 | .002 |
| | P2 | P3 | .977 |
| | | P4 | .924 |
| | | P5 | .956 |
| | P3 | P4 | .999 |
| | | P5 | .779 |
| | P4 | P5 | .672 |
| Dry weight | P1 | P2 | .000 |
| | | P3 | .000 |
| | | P4 | .000 |
| | | P5 | .003 |
| | P2 | P3 | .989 |
| | | P4 | .952 |
| | | P5 | .967 |
| | P3 | P4 | .999 |
| | | P5 | .845 |
| | P4 | P5 | .750 |

Growth was negative in P4, where all plants died. Growth was positive in all other parallels but varied largely between parallels. Highest growth was seen in P1, with an average end weight of almost 89 g (Fig. 17), representing a biomass increase of 4000 %. End weight for other parallels ranged from 3,01 g (P3) to 21,73 g (P5) (Fig. 18).

Daily growth ranged from -0,07 g/day to 3,10 g/day (Fig. 18). Giving growth rates in percent: 142,6%, 11,99%, 0,22% and 12,84%, for P1, P2, P3 and P5. Standard deviation was high in P1 and P5 compared to other parallels. The final result of growth per parallel was 707,4 g, 83,71 g, 23,82 g and 77,36 g respectively.

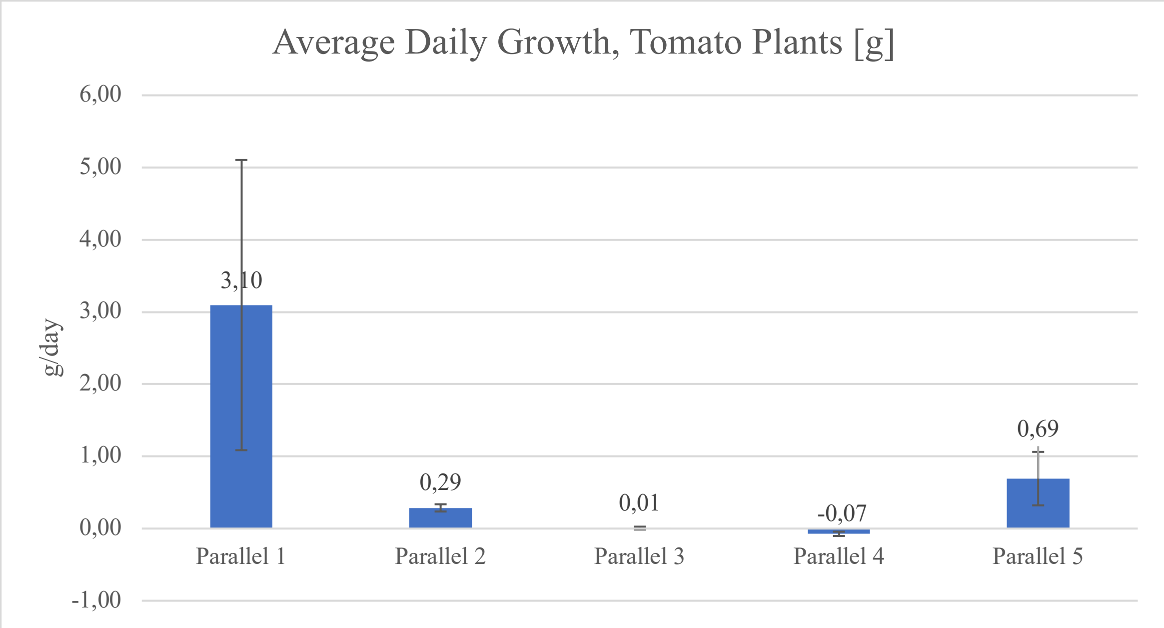


*Figure 18 Average daily growth for tomato plants in grams with standard deviation.*

Four parallels were measured for dry weight. Results showed similar reductions in percent from wet weight to dry weight, for the parallels (under 2% difference) (Tab. 8).

*Table 8 Difference in wet and dry weight for tomato plants.*

| Tomato plants | Wet Weight [g] | Dry Weight [g] | Change in Weight [g] | Change in % |
|---|---|---|---|---|
| Parallel 1 | 88,83 | 10,23 | 78,6 | 88,73 |
| Parallel 2 | 10,41 | 1,11 | 9,3 | 89,29 |
| Parallel 3 | 3,01 | 0,36 | 2,6 | 87,73 |
| Parallel 4 | 0 | 0 | 0 | 0 |
| Parallel 5 | 21,73 | 2,39 | 19,3 | 88,9 |

### *3.1.2 Plant Height*

There was a statistically significant difference in aerial height between the parallels at the start, mid and end of the experiment (Start ($F_{(4,35)} = 36.664$, $p = 0.000$); mid ($F_{(4,35)} = 165.271$, $p = 0.000$); end ($F_{(4,35)} = 124.557$, $p = 0.000$)). P1 is statistically significant different from all other parallels and grew very well. P4 is statistically significant different as all plants died. P2 grew better than P3, but less than P5, still there was no statistically significant difference between the parallels. P3 grew a little less than P2, but enough to get a statistically significant difference between P3 and P5 (Appx. 12).

All parallels showed better growth in the second half of the experiment. P1 and P5 had positive results from the start. Other parallels had negative growth until the mid of the experiment (Fig. 19).

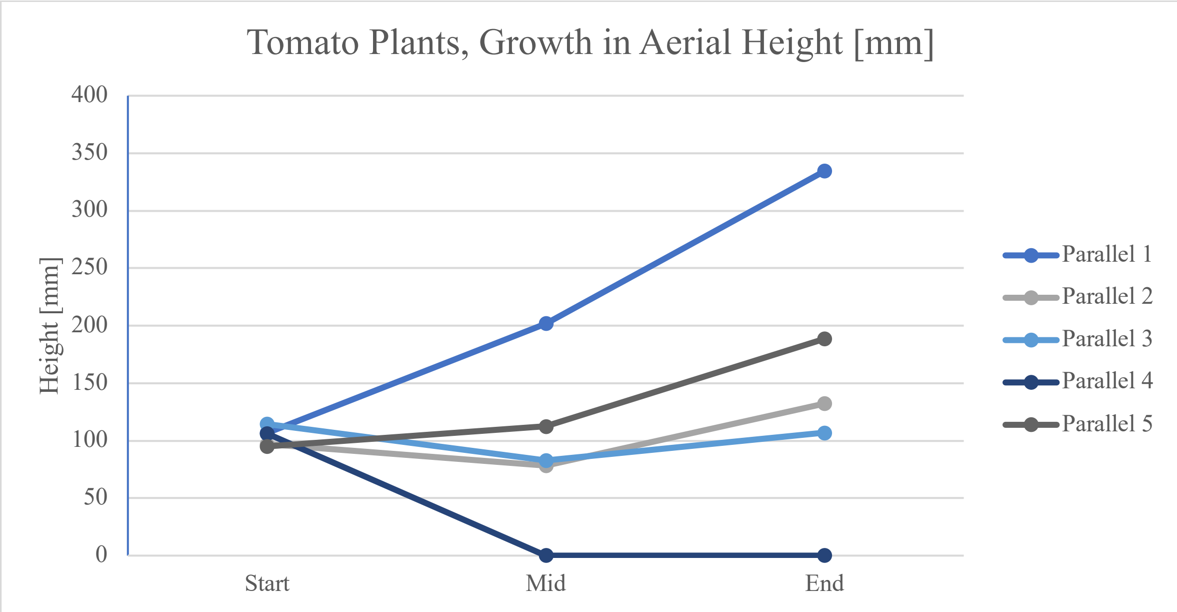



*Figure 19 Development of aerial height of tomato plants.*

Plants in P1, P2 and P5 had positive length growth, while the average growth in P3 was slightly negative. This was partly due to some plants dying, contributing to the negative mean. Growth was best in P1 with a daily average growth of 8,13 mm/day (aerial height), leading to a total length increase of 227,7 mm. Aerial daily growth for other parallels ranged from -3,79 mm/day (P4) to 3,34 mm/day (P5) (Fig. 20). Total growth in height ranged from -8,71mm (P4) to 11,31mm (P1).

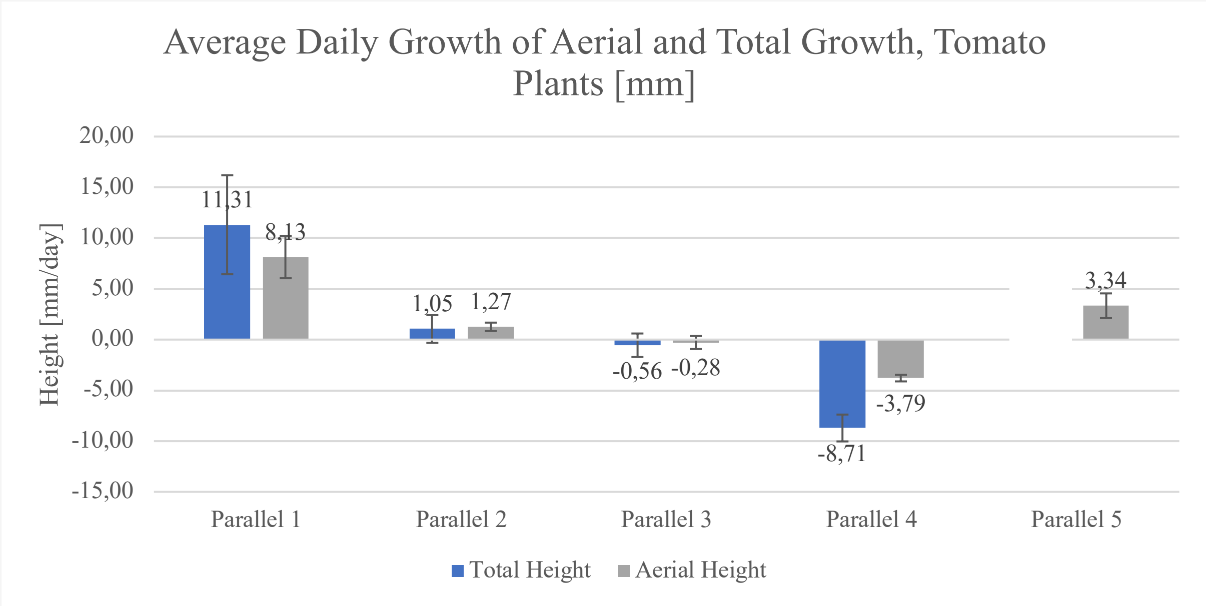



*Figure 20 Average daily growth for aerial and total height of tomato plants.*

### *3.1.3 Visual Registrations*

Visual registrations show the actual state of the plants (Appx. 14). There were significant differences between P1 and all other parallels. Plants were greener and branches and leaves developed at a much faster rate. Plants in P2 and P5 appeared to be healthy except some discoloring on leaves. P2 developed less new leaves and branches than P5. P3 had the lowest results with many yellow leaves. The plant lost many branches and appeared fragile. All parallels in waste product had roots covered in particles.

P1, P2, P3 and P5 had 11,1; 6,4; 3,9 and 8 branches in average per plant. P4 had no branches as all plants died (Fig. 22) (Appx. 14).

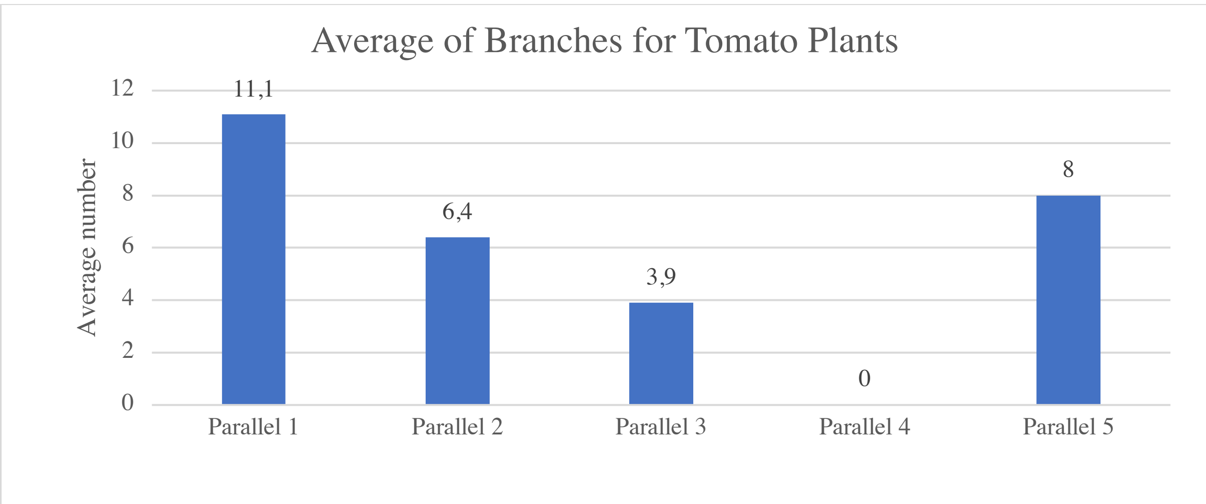



*Figure 21 Branches for Tomato Plants in the Different Parallels.*

### *3.2 New Zealand Spinach*

In P1 and P4 all plants lived through the whole experiment. For P2, P3 and P4 the number of dead plants were 3, 3 and 5 plants respectively. The plants that died, started withering after the first week, but were kept in the system for a period of time, to see if they would recover.

#### *3.2.1 Plant Weight*

Expected growth for each parallel with New Zealand spinach was 400g (see page 16-17).

Start weights in all parallels were relatively similar, between 1 g (P1) and 1,2 g (P2) (Fig. 22). Results were excluded by the ANOVA as all plants in one parallel had the same weight (Appx. 11). Growth was negative in P2, P3, P4 as several plants died and the average daily growth was low (Fig. 24). P5 had a positive growth with an end weight of 3,53 g. Growth was highest in P1, with an average end weight of almost 14 g (Fig. 23), representing a biomass increase of 1276,67%. End weight of other parallels ranged from 0,23 g to 0,50 g.

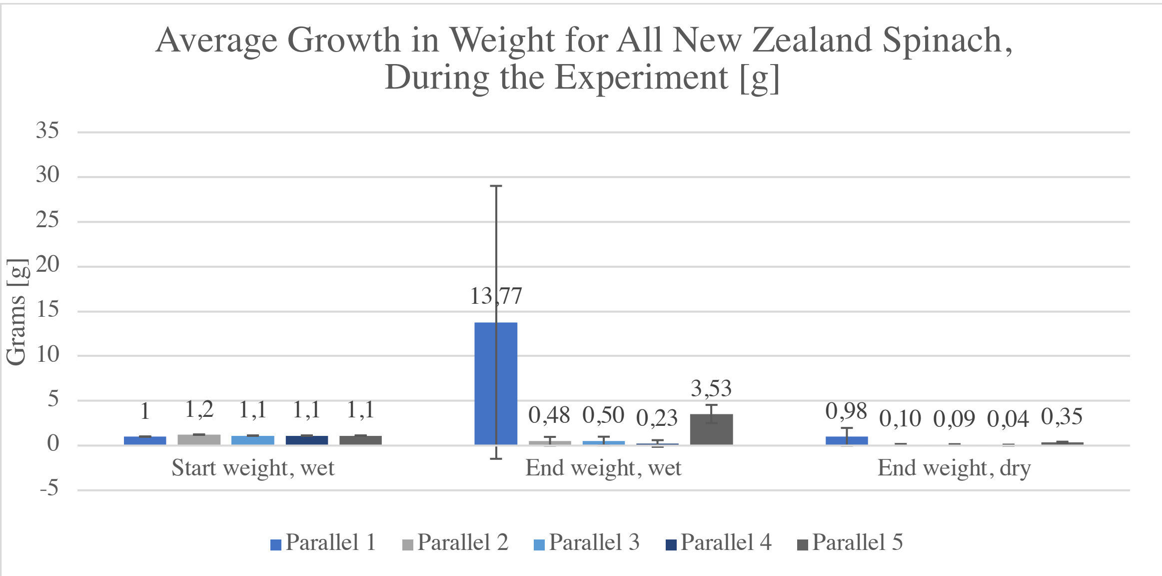



*Figure 22 Growth in weight for New Zealand spinach, start and end of the experiment.*

There was a statistically significant difference between parallels in end weights (F (4,35) = 5.645, p= 0.001) (Appx.11). The Tukey test show a statistically significant difference in wet and dry weight between plants of spinach in P1 and all other parallels, except P5 (Tab. 7). There was no statistically significant difference between the other parallels (Tab. 9).

*Table 9 Tukey Post Hoc Test for New Zealand Spinach.*

| New Zealand Spinach | Parallel | Parallel2 | P-value |
|---|---|---|---|
| End weight | P1 | P2 | .004 |
| | | P3 | .004 |
| | | P4 | .003 |
| | | P5 | .159 |
| | P2 | P3 | 1.000 |
| | | P4 | 1.000 |
| | | P5 | .956 |
| | P3 | P4 | 1.000 |
| | | P5 | .958 |
| | P4 | P5 | .943 |
| Dry weight | P1 | P2 | .006 |
| | | P3 | .005 |
| | | P4 | .011 |
| | | P5 | .252 |
| | P2 | P3 | 1.000 |
| | | P4 | .999 |
| | | P5 | .914 |
| | P3 | P4 | .998 |
| | | P5 | .903 |
| | P4 | P5 | .965 |

Daily growth ranged from -0,03 g/day (P2 and P3) to 0,46g/day (P1) (Fig. 23). Giving growth rates in percent: 45,6%, -2,17%, -1,96%, -2,8% and 7,77% for all parallels respectively. Standard deviation was higher in P1 and P5 compared to other parallels. The final result of growth per parallel was 115,04 g, 3,43 g, 3,73 g, 1,71 g and 12,69 g.

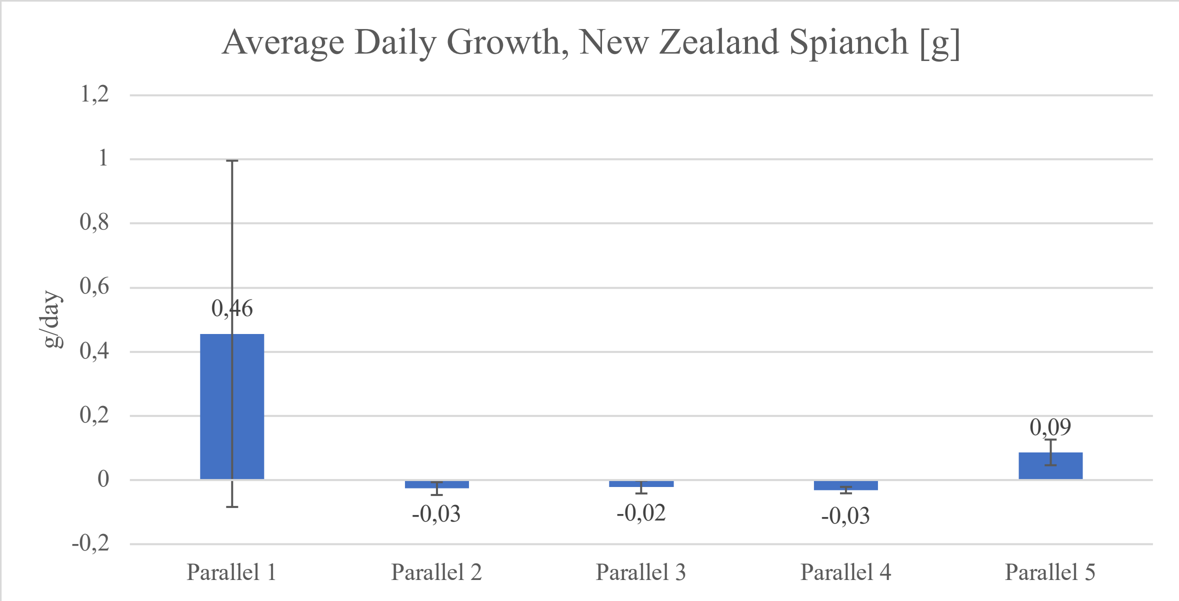



*Figure 23 Daily growth for New Zealand Spinach in grams with standard deviation.*

All parallels were measured for dry weight. Changes from wet to dry weights differed widely between 34,35% to 91,79% (Tab. 10).

*Table 10 Difference in wet and dry weight for New Zealand Spinach.*

| New Zealand Spinach | Wet Weight [g] | Dry Weight [g] | Change in Weight [g] | Change in % |
|---|---|---|---|---|
| Parallel 1 | 13,77 | 0,98 | 12,8 | 91,79 |
| Parallel 2 | 0,48 | 0,1 | 0,4 | 51,01 |
| Parallel 3 | 0,5 | 0,09 | 0,4 | 53,75 |
| Parallel 4 | 0,23 | 0,04 | 0,2 | 34,35 |
| Parallel 5 | 3,53 | 0,35 | 3,2 | 88,78 |

### *3.2.2 Plant Height*

There was no statistically significant difference in aerial start height between the parallels at the start ($F (4,35) = 0.738$, $p= 0.573$). At the mid of the experiment there was a statistically significant different between P1 and other parallels, except P5. All other parallels were not statistically significant different. Growth differed substantially between P1 and all others. At the end, P1 were statistically significant different from all other parallels. While other parallels were not statistically significant different (Appx. 12).

All parallels had negative growth in the start and positive growth in the second half of the experiment (Fig. 24).

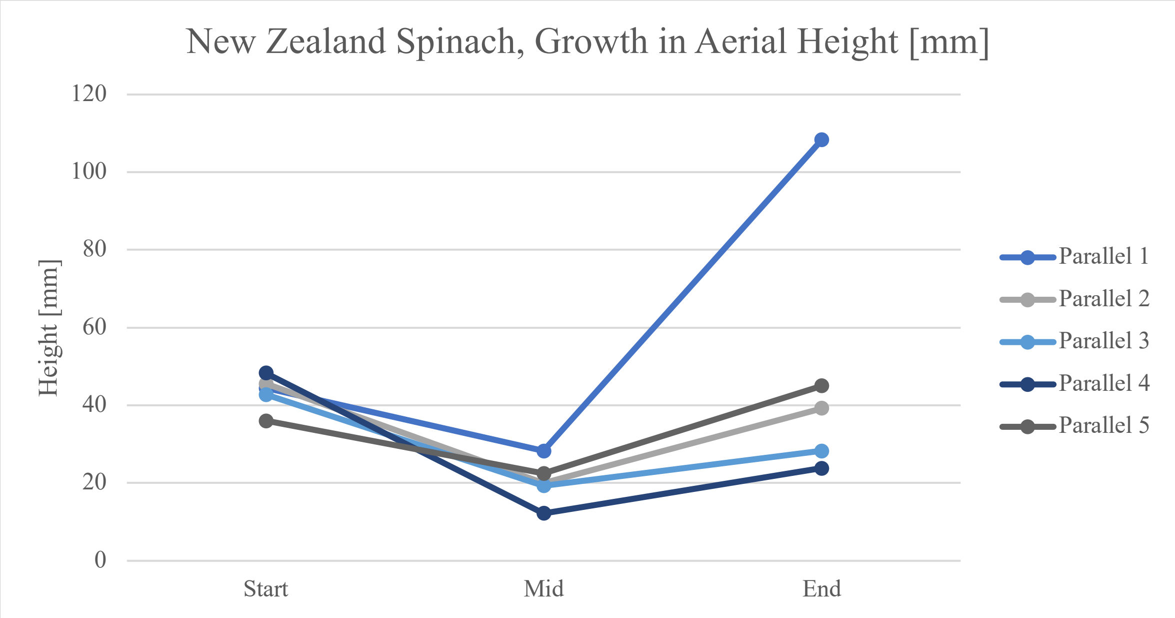



*Figure 24 Development of aerial height of New Zealand plants.*

Plants in P1 and P5 had positive length growth, while the average growth in P2, P3 and P4 was slightly negative. As with tomato plants, the means was affected by some plants dying. Growth was best in P1 with a daily average growth of 2,28 mm/day (aerial height), leading to a total length increase of almost 64 mm. Aerial daily growth for other parallels ranged from -0,88 mm/day (P4) to 0,32 mm/day (P5) (Fig. 25).

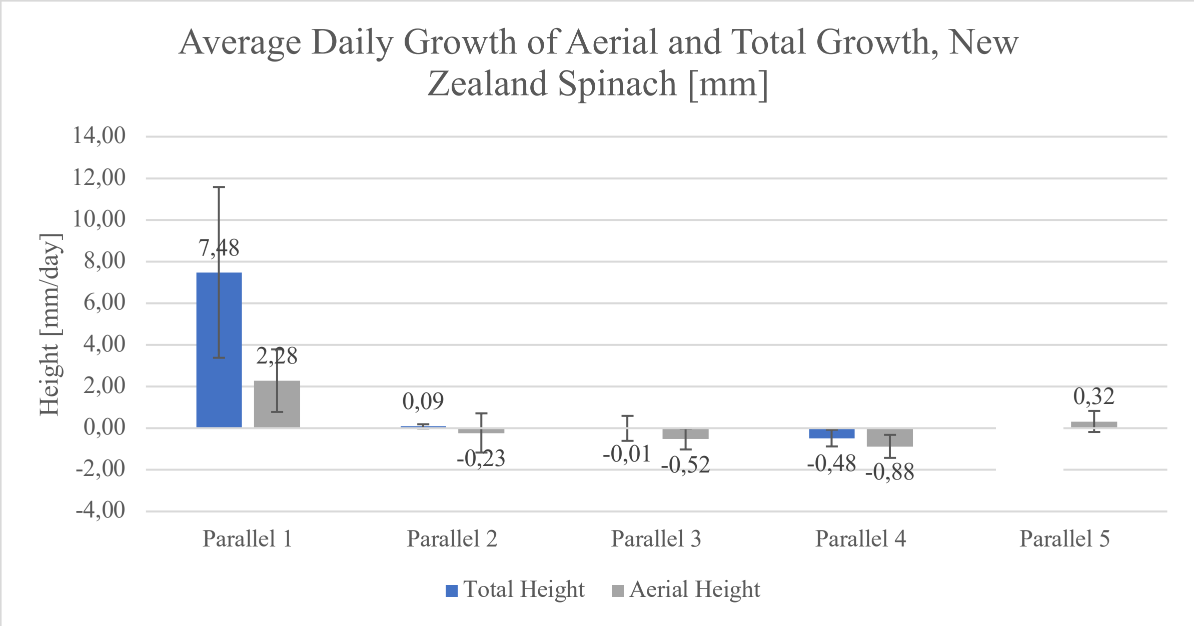



*Figure 25 Daily growth for aerial and total height of New Zealand Spinach.*

Dividing average growth into different sections gives insight in when plants grew the most. The growth in aerial height was much higher from the mid of experiment to the end. Growth of P1 increased with 6,9 mm/day in the second half (Tab 11).

*Table 11 Growth for aerial height [mm] for different periods during the experiment.*

| Parallel | Growth rate first half | Growth rate second half | Growth rate total |
|---|---|---|---|
| 1 | -1,2 | 5,7 | 2,3 |
| 2 | -1,8 | 1,4 | -0,2 |
| 3 | -1,7 | 0,6 | -0,5 |
| 4 | -2,6 | 0,8 | -0,9 |
| 5 | -1,0 | 1,6 | 0,3 |

P1 grew from 44,4 mm to 108,3 mm, with a growth of 2,3 mm/day. If the growth of 5,7 mm/day from the second half applied for the entire experiment the results would be 204,4 mm/day aerial height. All other parallels would have a better result as well (Tab. 11).

### *3.2.3 Visual Registrations*

Visual registrations show that plants in P1 developed much more than any other parallel (Appx. 14). These plants developed large and green leaves rapidly. Roots were significantly more developed. P2, P3 and P4 had lower and similar results. Many leaves turned yellow and barely any new development could be seen. All roots were covered in slime. In P5 the plants were green and developed large leaves.

Plants in P1 developed an average of 23,6 leaves and 4,1 branches. For P2, P3 and P4 the results were 4,7; 3,6 and 2,8 respectively. All parallels with 1 branch. P5 had an average of 7,5 leaves and 1,3 branches (Fig. 26) (Appx. 14).

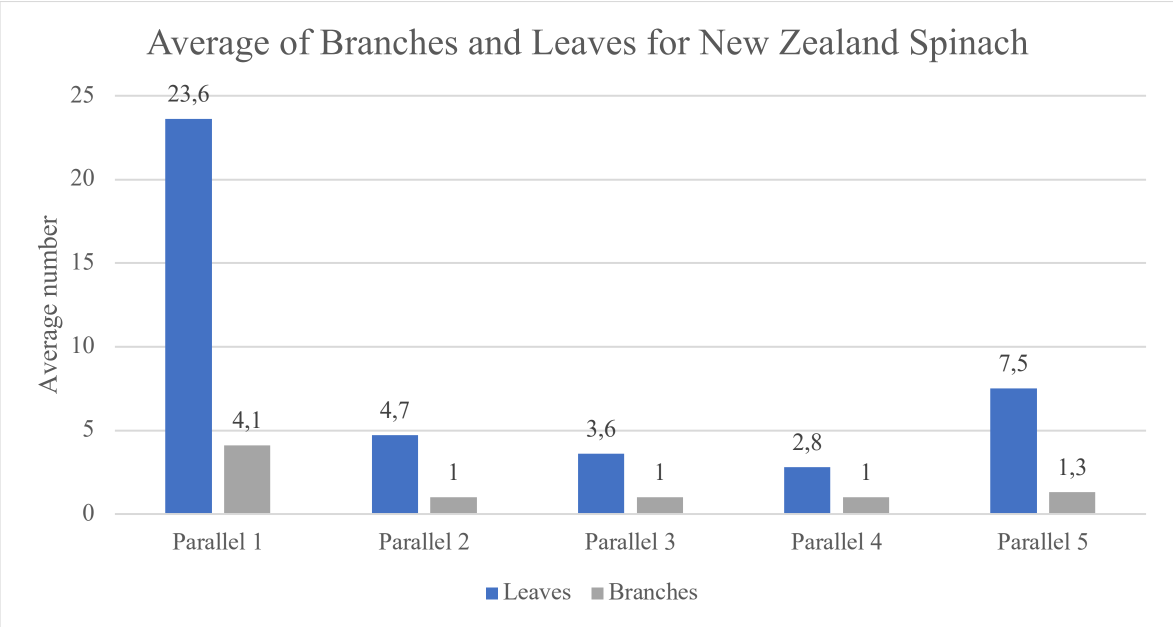



*Figure 26 Leaves and branches for New Zealand spinach.*

## *3.3 Hypotheses (Confirmed or Disproved)*

1. There will be a difference in growth between plants grown in hydroponic solution and in waste product.
   d. The parallel with hydroponic solution will provide the best result in growth
   Answer: Yes, the results confirm the hypothesis. Results clearly show a much higher growth in hydroponic solution.

   e. Waste product as nutrients will provide as good a growth as the hydroponic solution.
   Answer: No, the results disprove the hypothesis. Plant grew less in waste product even when efforts were made to secure levels of nitrogen and phosphorus

2. Plants in hydroponic pipes will grow better than soil parallels.
   Answer: No, the results disprove the hypothesis. Plants grew better in soil when irrigated with higher salinities and waste product.

3. There will be a difference in growth between plants grown in different salinities.
   a. Tomato plants grows best at low salinities and dies in high salinities.
      Answer: Yes, results confirms this hypothesis. The exception being tomato plants in soil, grown in higher salinities.

   b. New Zealand spinach grows best at the highest salinity.
      Answer: No, the results disprove the hypothesis.

   c. New Zealand spinach grows better than tomatoes at higher salinities.
      Answer: Yes, results confirms this hypothesis.

# 4. Discussion

## *4.1 Material and Methods*

Covid-19 led to many restrictions for this research. Finding the right materials, measuring instruments, sensors and tools was difficult in the midst of a pandemic and in quarantine. Analysis could not be carried out as laboratories at NTNU were closed. Alternative tools and methods had to be used.

Natural daylight and temperatures were not sufficient to germinate and grow seedlings, during the Norwegian spring. An indoor growing space with artificial light was made. One light source, giving a LUX reading of 5000, was not sufficient for robust growth in plants (62). Additional lights were added and increased light intensity, but only to 16.000 LUX, which is 20% short of the 20.000 LUX needed for robust plant growth (62). One can assume that results would be better if a higher LUX was achieved throughout the first growing phase.

Plants could not be moved to the greenhouse until temperatures were above freezing. Roots got intertwined as plants stayed in nursery pots for longer than planned. Recommendations are to start production when outside temperatures allow it. In case of larger productions or productions throughout the year, heated indoor facilities are recommended.

The build of the system was straight forward, following the blueprints.
The water flow was not optimal for the first plants in the pipes, it was therefore decided to leave the first hole empty. This way the water spread more, and it was easier to access the valves. The consequence of this was having a lower amount of plants for statistical analysis. Recommendations are to include a distance between the valve and the first plant of 100 mm, or more.

As roots grew larger, water resistance increased. This led to some water being pressured back up the pipe and through the holes drilled for the strips. By using larger pipes and better suited valves and mounting such leakages could be avoided. Using a garden hose was a low-cost alternative, which worked very well for a one-month experiment. For a longer operating system, plastic pipes would be preferred to guide the water.

The water pumps chosen for the system were designed for use in hydroponic systems. A concern was that the waste product would clog the pump. This did not happen as much of the particles and nutrients settled at the bottom of the collection buckets. Nutrients might dissolve over time, but this would probably happen faster with more motion in the water. A system with water stream would not let particles settle, but this would again affect the pump. Water analysis could be carried out to see if there is a difference in nutrient content. For future projects, this should be considered.

The process of transplanting plants from soil to net pots was difficult as roots were entangled. Some roots were damaged in the process, but it was thought that as long as there was a significant number of roots left, the plants would heal itself. Therefore, it was not expected to have an effect on results, except from an increase in standard deviation. Assuming that plants with damaged roots would take longer to reach the same growth rate.

If possible, hydroponic growth of seedlings is recommended. This way plants are already acclimatized to a wet environment. The transfer will be more optimal for plants and less roots would be damaged in the process. Plants in this experiment were negatively affected by the transplant. They started drooping immediately after rinsing the roots. Perhaps the temperature was too low. The temperature was increased, and plants drooped less but were still significantly affected by the process. Plants may have been impacted by salt or waste product. In P2-P4 plants were struggling more than in P1. As plants immediately started to drop, it seemed unlikely that this was the reasons. It was surprising that the changes could affect the plants so quickly.

For the New Zealand spinach, the roots were fewer and shorter. It was difficult to ensure that they reached the nutrient film. This could be why some of the plants died early in the experiment. Measures were made by ensuring that all plants were situated low enough in the net pots to reach the nutrients. By using smaller pipes or deeper net pots, this problem could be avoided. Recommendations are to make sure the pipes and net pots are optimal for the chosen species, as a universal structure might not suit the individual needs.

Under optimal conditions, the expected growth for tomato plants and New Zealand spinach was 500 g and 400 g. These amounts were calculated from the expected daily growth rate of tomato plants, 5,5% (66). P1 had the ultimate conditions regarding nutrients. Still, the New Zealand spinach did not grow as much as expected. Light intensity was not optimal from the start, which could affect the plant development (62). Air temperatures could not be measured and controlled throughout the day due to a lack of a temperature logger. To achieve acceptable temperatures, the system was enclosed with bubble wrapper. This seemed to have a positive effect as temperatures were higher inside the enclosing, than in the rest of the greenhouse.

Most plants had a negative growth in the first half of the experiment, then a positive growth during the second half. Could this be linked to the light and temperature conditions? The second half was from the mid of May, with warmer and sunnier days. This gave better growing conditions for the plants. Conditions like these throughout the whole experiment could give an increased growth of 96,1 mm for New Zealand spinach in P1 (Tab. 11). This is if light and temperature were the limiting factors.

The water temperatures registered ranged from 14°C to 29°C, but in reality, these temperatures might have varied more. Optimal temperatures were different for the species and suggestions from researchers vary. Baras (72) recommended 10°C - 21°C for New Zealand spinach, and 23,8°C –32,2°C for most tomato plants. Terejo (73) reported best results for spinach grown in 28°C, which is a much higher temperature. Spengler (74) stated that the ideal water temperature in NFT systems is around 18°C to 26°C. This means actual temperatures deviated from ideal temperatures.

Low temperatures in the water film, could inhibit growth (74). When temperatures rise above 22°C the oxygen demand would not be covered for tomato plants as the diffusion is increased (73). On sunny days the water in the parallels heated up quickly. Recommendations are to use light colored water containers. Water will be less affected by the sun, giving less of a temperature rise. Place containers on insulations mats to prevent heat from transferring to the ground.

When considering all this, the parallels in hydroponic solution still grew well. Tomato plants grew more than expected. Water temperatures in different parallels were similar (±2°C). P1 should be equally affected by wrong temperatures and light, as other parallels. This show that light and temperature must be within the right range for the species. A comparison between parallels would still give insight in effect of the use of saltwater and waste product as nutrients versus hydroponic solution. Considerations to be made are on how less growth and longer production time will affect the end products and economics.

New Zealand spinach in all parallels developed much less than expected. Results from hydroponic solution showed that the parallel had a very good growth, even though it was far from 400g. This meant that the expected growth was estimated incorrectly. There is an ideal concentration for nutrients, but high concentrations can limit growth (67). Nutrient requirements for New Zealand spinach was difficult to find. More research should be carried out to maximize the species growth in marine NFT systems. As other conditions were good for the spinach, it is possible that concentrations of some nutrients in the waste product, were too high and thereby limited growth.

The analysis of the waste product showed a tolerance of ±20% in several nutrients (Appx. 3) . Having such a wide tolerance level could lead to inaccuracies that affects the plants.

Calculations on nutrients to add weekly and daily, was also based on the expected growth. The hydroponic solution was calculated from mixing ratios on the product, and all tomato plants in this treatment grew much more than expected. Opposite, the plants in waste products grew less than expected and would probably not be able to take up all the nutrients. Which could lead to problems with excess nutrients (67).

Leaks led to complications calculating actual amount of nutrients in the different parallels. Up to approximately 300 ml of water could be lost in small leaks, this would mean up to 3% of the nutrients dissolved in the water. For bigger leaks, the whole growth medium was changed with fresh water, salt and waste product. This to be sure there would not be a lack of nutrients. At the same time this meant a difference in nutrient content for different water parallels. This could give a difference in growth. At weekly water change all parallels were changed and equal levels of waste product were added.

All plants in water setups with waste product were exposed to small particles that stuck on the roots. This created a slime (Appx. 10). Roots were carefully cleaned halfway through the experiment. More regularly cleaning of roots is recommended, but care must be taken to not damage them. Due to root development the water flow was impaired and reduced to approximately 1 l/min. The flow rate could be increased to achieve an optimal flow and also help clear the roots of slime. This was considered, but not carried out as there was a lack of literature to base any flow rate change on. For future projects gently cleaning or increasing waterflow for a few minutes every two days could lead to less particles on roots and more growth.

Connecting the system directly to land-based facilities and utilizing wastewater could minimize issues regarding temperature, particles on roots, nutrients and water flow. Nevertheless, the problem for fish farming industries is disposal of waste products (22). Efforts on taking advantage of waste products are therefore in focus in this project.

For registrations midway in the experiment, plants could not be measured properly due to sections covered by leca. A decline in growth half-way through the experiment could be seen (Fig. 19, 24). Weight could not be measured, and results were therefore incomplete. When finishing the experiment, some roots had grown significantly and were entangled. Some roots broke when untangling. This mainly happened for larger plants in P1 and could lead to less weight and length in the results. By removing plants for measurements regularly, a more correct image of the development could be achieved. To do this more plants and a bigger system would be needed.

## *4.2 Results*

### *4.2.1 Tomato Plants*

There was no statistically significant difference in start weight or height between parallels of tomato plants (One-Way ANOVA). This means any difference in end results must be an effect of different growing environments.

In the mid of the experiment P1 and P5 were not statistically significantly different for aerial height. This must be due to the high variation of plant size within the parallel. It was, therefore, difficult for the ANOVA to see that the parallels were different. Still, results were much better in P1 than P5, but it did not show because of the high standard deviation. By using more plants, the standard deviation would probably be lower. Results must be seen in accordance with registrations of weight and visual registrations.

In final wet weight and dry weight there was a statistically significant difference between P1 and all other parallels. The same is true for the results from height and visual registrations, where this parallel developed significantly more. Between all other parallels there were no statistically significant differences (height, wet and dry weight).

Height of tomato plants in all parallels grew more in the second half of the experimental period (Fig. 19). P2, P3 and P4 had negative growth the first two weeks and several plants died. Reasons for these results could be that plants needed time to acclimatize to a wet environment. Light and temperature conditions could also be of importance (see page 41 & 43). On the other hand, this decline could be caused by inaccuracies during the mid-experiment measuring.

Plants in hydroponic solution had the optimal growing condition regarding nutrients. Results show that these plants grew the most (Fig. 18, 20). They developed large root systems and the aerial growth was rapid. The daily growth rate (142,6%) was much higher than the expected 5,5%. New green branches and leaves developed continually. Stout (75) stated that small particles of organic waste will limit roots ability to absorb nutrients and water. It was therefore likely that clean roots were one of the reasons why the growth rate was so high, compared to other plants. All plants thrived, and it was surprising to see flowers within the limited time of the experiment. The fact that plants in hydroponic solution grew the most was not surprising as the nutrient solution was specially made for growing hydroponic vegetables. The final total growth in weight for P1 (780g), compared to the expected growth (500g), proved that the system worked well for hydroponic growing.

Plants grown in waste product and freshwater (P2) developed well but compared to plants in hydroponic solution (P1), the growth rate was much lower (11,99% daily) (Fig. 18). Still, the rate was surprising, as it was more than twice the expected growth (5,5%). Height and weight grew in accordance with one another (Fig. 18, 20). Roots were covered in particles which might have reduced the nutrient uptake (Fig. 16).

It was expected for plants to grow in this parallel as there was no salinity that could harm the plants. The only difference between P1 and P2 was that one had nutrients from hydroponic solution and the other from waste product. This meant that the nutrient composition and particles on roots, made all the difference.

Plants in waste product and 5ppt salt (P3) did not develop much after the transplant (0,22%). There was a reduction in height and a small increase in weight within the first two weeks of the experiment. Several leaves and branches had to be removed during the experiment so plants would not be negatively affected by unhealthy branches, this also caused less weight. Roots were covered in particles here as well. Plants looked fragile and not strong enough to carry fruits.

Contrary to the findings of Fronte, this research showed that tomato plants does not grow significantly at 5ppt (5g salt/l) (47). This is only 1g salt/l more than in Frontes research. The only difference between P2 and P3 was the salinity. There was no statistically significant difference in end weight between the parallels, but the average weight, height and numbers of branches was systematically lower for P3, which was grown in water with 5 ppt salt. All plants in waste product and 13ppt salt died (P4). These results tied well with previous studies wherein tomato plants are moderately sensitive to salinity (49) (76) (77).

Soil plants (P5) developed well, with a higher average daily growth rate (12,84%) than expected (5,5%) (Fig. 18). Height and weight increased in accordance with one another (Fig. 20). Plants were not affected by the irrigation in the same way as plants in P4.

Salt tolerance seemed to be higher in soil than in a hydroponics system for these tomato plants. All hydroponic plants in the highest salinity died, while the soil plants had a good growth rate. These plants were irrigated with the same water treatment. A reason for this could be that plants in soil needed less water and therefore was less affected by salt. Another reason could be that the actual salt concentration around roots would be smaller as the salt was distributed in the soil. A possibility is that salt concentrations would rise over time and affect the plants as salt accumulates in the soil. The growth of soil plants was better than for all other parallels with waste product. This might be a result of soil plants being able to access extra nutrients from the soil, contradictory to hydroponic plants. On the other hand, it could be a result of plants not being directly in contact with nutrients like in the NFT. If there was too much nutrients in the NFT, soil plants were not affected as badly by this. Maybe because nutrients become less concentrated in the soil. Soil plants did not suffer from problems with slime on the roots, which was an advantage.

From the results it was clear that tomato plants had a higher growth in hydroponic solution than waste product. If one wants to grow tomato plants with waste product as nutrients, better results are obtained in soil or NFT without salt. Negative effects of salt accumulation over time, must be further researched for soil plants.

All parallels of tomato plants reduced the weight with approximately the same percentage from wet to dry weight. It therefore seemed as plants contained approximately the same amount of water in different salinities (Tab. 8). This showed that plants were able to uphold a changed osmotic pressure, as a consequence of higher salinities. An increased water uptake and the ability to keep this water, might seize energy which should initially be used on growth.

### *4.2.2 New Zealand Spinach*

There was no statistically significant difference in start weights between parallels of New Zealand spinach (Appx. 11). This meant the same as for tomato plants, that all differences in end result must have been an effect of different growing environments.

There was a statistically significant difference in wet and dry weight between P1 and P2, P3 and P4, but not P5. This finding was underlined by the other measures, as plant P1 and P5 developed into higher, healthier looking plants with more branches than those in P2, P3 and P4. There was no statistically significant difference between all other parallels for wet and dry weight.

Analysis of aerial height showed no statistically significant difference in start height. For mid and end height the differences were statistically significant. New Zealand Spinach grew more horizontally and therefore results of height must be seen in accordance with results in weight. In addition, the fact that dead plants were removed and registered as zero also contributed to the negative growth on results both in height and in weight measurements.

Plants in the hydroponics solution (P1) grew less (115,04 g final weight) than the estimated growth (400g). The initial estimates should be reduced for future studies as plants in hydroponic solution had a very good growth (45,6% daily) but was still far from 400g (See page 46). Plants developed quickly in terms of both height and weight. The average growth rate was much higher than for other parallels.

Plants in fresh water and waste product (P2) had a negative growth (-2,17% daily). The result could be negative as several plants died and were registered as zero in the measurements. Looking at the plants that survived they were small, but green. Stout (75) stated that nutrient uptake is limited when roots are covered in particles. This could be the reason for low growth, the same as for tomato plants.

Plants in waste product and 5ppt (P3) had a negative growth in height and weight (-1,96% daily), and several plants died. It was surprising that results were negative as it is a halophyte species. Same as for P2, registration of dead plants and particles on root had a negative effect.

Plants in waste product and 13ppt (P4) had a negative growth (-2,8%) like P3. This was the parallel expected to bring the best results for the halophyte. Student at UFSC stated that in previous experiments growth has been highest at 13ppt (57). This has not been the case here, as the daily growth was the lowest for aerial height (-0,88 mm), final weight (1,71 g) and most plants died in this parallel. Differences in results between the experiments must be linked to other parameters then salt (lights, temperature, nutrients, size or age of plants). The climate in Brazil is widely different from the Norwegian one. More sunlight and higher temperatures could provide more robust start plants and higher growth ratios (62).

Soil plants (P5) were irrigated with the same water treatment as P4. These plants had a positive growth rate (7,77%) and grew better than plants in P4. Results for aerial height also showed good growth (Fig. 25). New Zealand Spinach developed more horizontally and by looking at visual registrations and weight it was clear that this plant grew. Plants developed larger leaves than other plants in waste product. The soil plants gave the second-best result for growing spinach. The reasons for this could be the same as for tomato plants – with less slime on roots, and soil either adding missing nutrients or making irrigation less concentrated. New Zealand spinach naturally lives in harsh and dry environments and does not need much irrigation to grow (60). This way the plant might have been less exposed to excess nutrients.

The only difference between growing conditions for P4 and P5 was hydroponic growing versus soil. This created a significant difference in growth (Tab. 22-26). Plants in soil developed more than twice as many leaves (Fig. 26).

There were big differences in percent, between the parallels in wet and dry weight. The changes for P2, P3 and P4 were much smaller, than for P1 and P5. Further research on the subject, could be carried out in future experiments, to know why these results were found.

The New Zealand Spinach did not show the results expected for a halophyte in saline water. Reasons for this must have been the composition or amount of waste product. All hydroponic parallels with waste product had a negative growth rate. Either the plants suffered from an insufficient or an excess amount of nutrients, which both could prevent growth (67). It is possible that the New Zealand spinach was sensitive to other elements in the waste product, for example metals. Future research could give more insight on the subject.
Nutrients were calculated to fit the high nutrient need of tomato plants. Perhaps tomato plants had a faster nutrient uptake than spinach, and there were not enough nutrients for the spinach to grow. On the other side, the spinach could be negatively affected by an excess of nutrients.

Previous research showed that spinach grows well in hydroponics system (46) and in saline water (59). Results clearly showed that New Zealand spinach grew well in hydroponic systems, but not in the combination with waste product. The nutrient composition seemed to be wrong, or the particles prevented nutrient uptake. Closer water analysis should be made to find the problem.

### *4.3 Overall results*

The simple structures of the hydroponic system worked well for the experiment. For future projects it will be easy to modify and scale it up to a larger size. By adding pumps to continuously and automatically add nutrients, the workload for the operator would be reduced, while the nutrient flow would be secured.

The results from the One-Way ANOVA showed similar results for both species (except mid measurements for P5, New Zealand spinach). Plants grown in hydroponic solution grew faster and were healthier than plants in P2-P5 (tomato plants) and P2-P4 (New Zealand spinach). It was expected to achieve more growth in this parallel than the others, as it was used to show the “ultimate” growth of the plants. Still the results were surprising as the growth was remarkable, compared to the other parallels. This showed that using the right nutrients was crucial to obtain this kind of growth rate. Other parallels with waste product as nutrients did not develop in this manner, even though growth in fresh water and soil was good for tomato plants. There could be several reasons for these results; wrong composition of nutrients, an excess or lack of nutrients.

The waste product contained elements that could affect plants negatively. Cadmium, Mercury and Zinc were found in the specific waste product used (Appx. 3). These elements could harm the growth of the plants. The high amounts of zinc degraded the product and placed it in quality class 2 of the fertilizer trade regulations (Gjødselvareforskrift) (Appx. 13). This meant no more than two tons dried waste can be used per acres over a 10 year period and it limits its use as a fertilizer (22).

Most plants in parallels with waste products grew less than expected. Exceptions being P2 and P5 for tomato plants. From calculations on nutrients it was expected that plants would have sufficient nitrogen and phosphorus to grow. On the other hand, these calculations were made based on an expected growth. Only P1 of tomato plants grew more than this expected growth. As other plants grew much less, they would not be able to utilize all the nutrients, and the excess might limit the plants growth. Too much nutrients could lead to problems for the plants water uptake (67). It was difficult to state whether it was the salt or the waste product that created the main problem for the plants, as it was not possible to carry out necessary tests and analysis throughout the experiment. One therefore had to rely on available information to understand the results.

Best results for growth with waste product as nutrients, was found in soil plants, for both species. These findings were in accordance with findings reported by Brod and Høst, who reports positive results for waste product as fertilizers in agriculture (26, 27).

The fact that roots were covered in slime could have more of an impact then first expected. There was a clear difference in roots systems and growth between plants in hydroponic solution and waste product (Fig.16). Nutrient uptake for roots covered in particles was limited (75). This might have caused the low growth rate and dead plants. By adding a settling chamber (2) or a filter this problem might be avoided, as much of the particles would be removed from the nutrient film. The particles might have been the main problem for growth in this experiment. It would be interesting to see if there would be a difference in growth when using filtered water.

Previous research showed that aquaponics systems in combination with freshwater hatchery facilities for salmon is possible (39). Research on adding dried waste product from land-based systems, in hydroponic system was not found. Neither was research on aquaponics systems in combination with land-based facilities with increased salinity. The challenges in combining systems like these, was finding the right amount of nutrients for the specific plants. It was also a challenge to avoid particles on roots and other potentially negative materials (metals, etc.). By having the right equipment, this should be fairly easy to monitor and control. More research should to be made on why the New Zealand Spinach did not grow in a hydroponic system with waste product as nutrients. Are particles on roots the main problem?

With the knowledge obtained from this project, there are certain things that would be changed if carrying out a similar project in the future. Most importantly a filtration system would be added and if slim appeared, roots would be cleaned regularly. Close monitoring and analysis of nutrients, salinity, pH and temperatures would be carried out. A large-scale experiment would be made with several plants. This way more accurate weight measurements could be carried out through the experiment. Seeds would be sown directly in rockwool.

### *4.4 Possibilities*

A rising population (4) in combination with food (5) and water scarcity (6) show the need for newer ways to produce sustainable food. In this thesis hydroponics in different salinities, with waste product from land-based aquaculture as nutrients, has been tested to grow vegetables. As seen in the results, this has not shown much promise. At this point in time and based on this experiment, it cannot be seen as a solution to increase food production. Nevertheless, this can be due to mistakes made during the experiment or the fact that the quality of the waste product could be degraded as it was from 2017.

By doing more research on the area, it should be possible to carry out a similar project where at least New Zealand spinach would grow in saline water. In this case, the structure of the system should be optimized to see if higher growth can be achieved. By being able to carry out more analysis on both waste product and water quality it would be easier to map out why the plants develop as they do. Testing several plants in future experiments, can give more insight in optimal species to grow in a system with waste products and higher salinities. A possibility is to test plants already growing under such conditions, for example macro algae. An idea is to test the algae Ulva in a system with higher salinities. The species is grown together with shrimps in bioflocc at the UFSC. This would be an interesting possibility to explore. In such case, the system would need some modifications to suit algae growth.

The plant growth might take longer with waste products, then in commercial nutrient solutions, as seen in this experiment. Nevertheless, the point of this research is to further utilize resources from land-based aquaculture. Saline hydroponics with waste product or aquaponics directly connected with land-based aquaculture has a big potential. It could lead to less water being needed for vegetables production. Today 70% of freshwater withdrawals goes to agriculture (7), by combining vegetable and fish farming, it might be possible to reduce these numbers. It would also mean putting less stress on the environment, which is already degrading (9). Today 50% of all habitable land on earth is used for agriculture (8). Considering how this land has decreased over the last 20 years (10), and how agriculture cannot be further increased in a sustainable way (11, 12), it seems like something worth trying. Marine aquaponics systems can be set up in areas with less freshwater resources. Up to 15% of underdeveloped land can be used for saltwater agriculture, for example through systems like this (45).

It is already known that aquaponics works in combination with freshwater aquaculture (39), so there should be a potential for a combination of marine aquaculture and halophytes. As seen by several researchers (40, 41), marine aquaponics systems with halophytes works.

As systems like these are easy to modify and takes up less space, there are endless possibilities for different structures (30). Food production can take place in buildings and use more vertical space, instead of vast land areas. In cities vertical farms can be a solution (31). This experiment was carried out in a small greenhouse in a private garden and did not take up much space.

Land based aquaculture facilities are increasing (17), and this also gives increasing possibilities for aquaponics systems, both fresh water and saltwater based. Advantages by growing aquaponically (29) in combination with the fact that aquaculture is the most sustainable way to produce protein (15), gives an impression that this will be one of the important ways of food production in the future. In addition, big amounts of both nitrogen and phosphorus ends up in the Norwegian sea, and probably all over the world (26). By recycling and utilizing these valuable resources it is possible to create less waste and thereby a more sustainable production of food.

Starting up a large-scale experiment which is connected to a Norwegian hatchery facility, would be the next step for this project. Involving people experienced in fields such as aquaponics, aquaculture (RAS-systems), plant biology and agriculture, the probability of succeeding would be much higher. This way the potential could be researched, and more advanced technology could be used. It would be interesting to see if this is a real possibility for sustainable vegetable production. The economic aspect which has not been in focus in this thesis, must be further research.

Another option is for producers to export dry waste to developing countries. Producers could benefit from a small profit instead the cost of disposal (23). Hydroponic systems could utilize the low-cost nutrients with the advantage of warmer climate. Before this could happen, further experiments should be made regarding nutrient content, species, particles on roots, temperature, light and hydroponic germination. Calculations on the economic aspect has to be made to research the possible of exporting the waste product, and still profit or break even.

# 5. Conclusion

It is possible to build a relatively simple nutrient film technic system (NFT) to grow plants hydroponically. Using dried waste products at different salinities and directly in an NFT, was not optimal for growth. Tomato plants and New Zealand spinach did not develop as hoped in these exact water treatments, which could be due to compositions of the growth mediums. Plants can grow hydroponically in waste products, but preferably with no salt. Tomato plants under such conditions, grew twice as much as expected. Results demonstrate that the use of waste products and salt is more efficient as fertilizers in soil plants at this point in time. Further research and analysis must be made to ensure that the nutrients composition fits the specific species. Particles on roots seemed to be an issue for growth in this experiment. For future experiments a filtration system should be added.

The focus of this thesis has been to find alternative ways of utilizing waste products for sustainable vegetable growth. Even though the growth rate is lower than in hydroponic solution, the goal is to utilize waste products that would otherwise be disposed. Recycling nutrients this way will contribute to a more sustainable food production. There is still a lot of research that needs to be done before reaching this goal. The next step would be integrating the system in a land-based facility with a continuous water flow.

# 6. Literature


1. Gardenerdy. The Surprising Benefits and Types of Aquaponic Systems https://gardenerdy.com [Available from: https://gardenerdy.com/types-of-aquaponic-systems.
2. Pinheiro IC, R. F. S., Vieira, F. N., Gonzaga, L. V., Fett, R. Costa, A. C. O., Magallón-Barajas, F. J., Seiffert, W. Q. Aquaponic production of Sarcocornia ambigua and Pacific white shrimp in biofloc system at different salinities. 2020 2020/03/30/. In: Aquaculture [Internet]. [734918]. Available from: http://www.sciencedirect.com/science/article/pii/S0044848619316114.
3. Worldometer. Current World Population [Available from: https://www.worldometers.info/world-population/.
4. UN. World population projected to reach 9.8 billion in 2025, and 11.2 billion in 2100 New York UN; 2017 [Available from: https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html
5. Godfray HCJ, Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S., Thomas, S. M., Toulmin, C. Food Security: The Challenge of Feeding 9 Billion People. Science [Internet]. 2010; 327(5967):[812-8 pp.]. Available from: https://science.sciencemag.org/content/sci/327/5967/812.full.pdf.
6. GRID-Arendal. Freshwater Stress 1995 and 2025 grida.no 2005 [Available from: https://www.grida.no/resources/5785.
7. FAO. Water for sustainable food and agriculture: A report produced for the G20 Presidency of Germany. Rome: Food & Agriculture Org.; 2017. Available from: http://www.fao.org/3/a-i7959e.pdf.
8. Ritchie H. How much of the world's land would we need in order to feed the global population with the average diet of a given country? ourworldindata.org: Our World in Data; 2017 [Available from: https://ourworldindata.org/agricultural-land-by-global-diets.
9. Wanza SN. What Is The Environmental Impact Of Agriculture? Worldatlas.com: World Atlas; 2018 [Available from: https://www.worldatlas.com/articles/what-is-the-environmental-impact-of-agriculture.html.
10. Food and Agriculture Organization of the United Nations F. FAOSTAT - Land use Fao.org: FaoStat; 2019 [updated 03.12.19. Available from: http://www.fao.org/faostat/en/#data/RL/visualize.
11. Food and Agriculture Organization of the United Nations F. TRANSFORMING FOOD AND AGRICULTURE TO ACHIEVE THE SDGs. Rome: FAO; 2018. Available from: http://www.fao.org/3/I9900EN/i9900en.pdf.
12. FAO. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome, Italy: FAO; 2018. Available from: http://www.fao.org/documents/card/en/c/I9540EN/.
13. NOAA. What is aquaculture? National Ocean Service: NOAA; 2019 [Available from: https://oceanservice.noaa.gov/facts/aquaculture.html.
14. European Commission. A short history - Aquaculture ec.europa.eu: European Commission; [Available from: https://ec.europa.eu/fisheries/cfp/aquaculture/aquaculture_methods/history_en
15. Troell M, Naylor, R. L., Metian, M., Beveridge, M., Tyedmers, P. H., Folke, C., Arrow, K. J., Barrett, S., Crépin, A., Ehrlich, P. R., Gren, Å., Kautsky, N., Levin, S. A., Nyborg, K., Österblom, H., Polasky, S., Scheffer, M., Walker, B. H., Xepapadeas, T., de

Zeeuw, A. Does aquaculture add resilience to the global food system? Proceedings of the National Academy of Sciences [Internet]. 2014; 111(37). Available from: https://www.pnas.org/content/pnas/111/37/13257.full.pdf.
16. Tidwell JH, Allan G. . The Role of Aquaculture. 2012. In: Aquaculture Production Systems [Internet]. [3-14]. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/9781118250105.ch1.
17. Espmark ÅM. Ulike typer oppdrettsanlegg Nofima.no: Nofima; 2019 [Available from: https://nofima.no/verdt-a-vite/ulike-typer-oppdrettsanlegg/.
18. Oirere S. Pure Salmon picks Lesotho for new African RAS salmon project seafoodsource.com: Seafood Source; 2019 [Available from: https://www.seafoodsource.com/news/aquaculture/pure-salmon-picks-lesotho-for-new-african-ras-salmon-project.
19. AquacultureID. RECIRCULATING AQUACULTURE SYSTEM www.aquacultureid.com: AquacultureID;  [Available from: https://www.aquacultureid.com/recirculating-aquaculture-system/.
20. Rambøll. Kunnskapsgrunnlag for rensing av utslipp fra landbasert akvakultur2019 22.10.2019. Available from: https://www.miljodirektoratet.no/globalassets/publikasjoner/m1568/m1568.pdf.
21. Rosten TW. Karakterisering av avløpsvann fra norske landbaserte settefiskanlegg 2015; 3. Available from: https://vannforeningen.no/wp-content/uploads/2015/06/2015_935380.pdf.
22. Nibio. Fiskeslam nibio.no: Nibio; 2017 [Available from: https://nibio.no/tema/jord/organisk-avfall-som-gjodsel/fiskeslam.
23. Egge H. Det nyttige krypet lever av slam fra fiskeoppdrett SINTEF.no: SINTEF; 2019 [Available from: https://www.sintef.no/siste-nytt/dette-nyttige-krypet-lever-av-slam-fra-fiskeoppdrett/.
24. Tuene S. Laksens biologi. In: Students at Biomarine Innovation, editor. Blackboard: NTNU; 2019.
25. Torrissen O, Norberg, B., Viswanath, K., Storhmeier, T., Strand, Ø., Naustvoll, LJ., Svåsand, T. Framtidsrettet matproduksjon i kyst og fjord 2018 08.08.2018; 23:[84 p.]. Available from: https://www.hi.no/resources/23-2018-Framtidsrettet-mat_1408.pdf.
26. Brod E, Haraldsen, T. K., Krogstad T. . Fiskeslam som nitrogengjødsel. Effekt av ulike behandlingsteknologier. NIBIO RAPPORT [Internet]. 2016; 2(2/118/2016):[10 p.]. Available from: https://nibio.brage.unit.no/nibio-xmlui/bitstream/handle/11250/2418973/NIBIO-RAPPORT_2_2016_118.pdf?sequence=1&isAllowed=y.
27. Høst. Høst kjøper slam fra settefiskanlegg Høst.no: Høst; 2019 [Available from: https://www.xn--hst-0na.no/aktuelt/hst-kjper-slam-fra-settefiskanlegg.
28. Fisheries and Aquaculture Department. The State of World Fisheries and Aquaculture 2018 (SOFIA) 2018. Available from: http://www.fao.org/documents/card/en/c/I9540EN.
29. Somerville C, Cohen, M., Pantanella, E., Stankus, A., Lovatelli, A. Small-scale aquaponic food production. FAO Fisheries and Aquaculture technical paper 589 [Internet]. 2014. Available from: http://www.fao.org/3/a-i4021e.pdf
30. Diver S, Rinehart, L. Aquaponics-Integration of hydroponics with aquaculture. HORTICULTURE SYSTEMS GUIDE [Internet]. 2000. Available from: http://backyardaquaponics.com/Travis/Attra%20Aqua.pdf.
31. Gaddagimath PB. Vertical Farming to Supplement Horticultural Food Basket of Urban and Peri-Urban Population in India. Jodhpur, India: Scientific Publishers; 2018. Available from: https://www.scientificpub.com/upload/pdf/871.pdf.
32. Blidariu F, Grozea, A. Increasing the Economical Efficiency and Sustainability of

Indoor Fish Farming by Means of Aquaponics - Review Scientific Papers: Animal Science and Biotechnologies [Internet]. 2011; 44. Available from: http://www.spasb.ro/index.php/spasb/article/view/287.
33. Fullbloom. Hydroponic Systems 101 Fullbloomgreenhouse.com 2019 [Available from: https://www.fullbloomgreenhouse.com/hydroponic-systems-101/.
34. Max. Hydroponic Nutrient Solution - The Essential Guide Green and vibrant 2019 [Available from: https://www.greenandvibrant.com/hydroponic-nutrient-guide.
35. The Aquaponic Source. What is aquaponics theaquaponicsource.com [Available from: https://www.theaquaponicsource.com/what-is-aquaponics/.
36. Jena A, Biswas, P., & Saha, H. . ADVANCED FARMING SYSTEMS IN AQUACULTURE: STRATEGIES TO ENHANCE THE PRODUCTION. Innovative Farming [Internet]. 2017; 2(1):[84-9 pp.]. Available from: http://innovativefarming.in/index.php/innofarm/article/view/232/181.
37. Østnes JE. Nitrogenholdige avfallsstoffer ndla.no: Nasjonal Digital Læringsarena; 2019 [Available from: https://ndla.no/nb/subjects/subject:42/topic:1:77165/topic:1:189720/resource:1:124465.
38. Kaiser MJ, Attrill, M. J., Jennings, S., Thomas, D. N., Barnes, D. K. A., Brierley, A. S., Hiddink, J. G., Kaartokallio, H., Polunin, N. V. C., Raffaelli, D. G. Marine Ecology. Second ed. New York, United States: Oxford University Press Inc.; 2011.
39. Rong R. Vi var nok kanskje litt tidlig ute i forhold til teknologien. SMP [Internet]. 2018. Available from: https://www.smp.no/nyheter/2018/07/12/--Vi-var-nok-kanskje-litt-tidlig-ute-i-forhold-til-teknologien-17109660.ece?rs4489411592490422077&t=1.
40. Boxman S, Main, K., Nystrom, M., Ergas, S. J., Trotz, M. Aquaponic System Produces Red Drum, Saltwater Vegetable Species Global Aquaculture Advocate 2015 [Available from: https://www.aquaculturealliance.org/advocate/aquaponic-system-produces-red-drum-saltwater-vegetable-species/.
41. Pantanella E. Integrated Marine Aquaculture-Agriculture: Sea Farming Out of The Sea. Faculty of Agricultural Science [Internet]. 2012 01.01.2012; M.S. Available from: https://www.aquaculturealliance.org/advocate/integrated-marine-aquaculture-agriculture/.
42. Srivastava LM. CHAPTER 16 - Abscisic Acid and Stress Tolerance in Plants. 2002 2002/01/01/ [cited 14.01.2020]. In: Plant Growth and Development [Internet]. San Diego: Academic Press, [cited 14.01.2020]; [381-412]. Available from: http://www.sciencedirect.com/science/article/pii/B9780126605709501581.
43. Khan MA, Ozturk, M.,, Gul B, Ahmed, M. Z. Introduction. 2016 2016/01/01/ [cited 14.01.2020]. In: Halophytes for Food Security in Dry Lands [Internet]. San Diego: Academic Press, [cited 14.01.2020]; [xxi-xxii]. Available from: http://www.sciencedirect.com/science/article/pii/B9780128018545000236.
44. Feng L, Ji, B., Su, B. . Economic value and exploiting approaches of sea asparagus, a seawater-irrigated vegetable Agricultural Sciences [Internet]. 2013; 4:[40-4 pp.]. Available from: https://www.scirp.org/pdf/as_2013110613294521.pdf.
45. Glenn EP, Brown, J. J., O'Leary, J. W. Irrigating Crops with Seawater. Scientific American [Internet]. 1998 [cited Full publication date: AUGUST 1998; 279(2):[76-81 pp.]. Available from: www.jstor.org/stable/26070601.
46. Ahmed AK, Johnson, K.A. . GROWING AUSTRALIAN NATIVE EDIBLE PLANTS USING HYDROPONIC TECHNIQUES. Acta Hortic [Internet]. 2000; 511. Available from: https://doi.org/10.17660/ActaHortic.2000.511.25.
47. Fronte B, Galliano, G., Bibbiani, C. . From freshwater to marine aquaponic: new opportunities for marine fish species production. Conference VIVUS – on Agriculture, Environmentalism, Horticulture and Floristics, Food Production and Processing and Nutrition [Internet]. 2016 20th and 21st April 2016. Available from:

https://www.researchgate.net/publication/303875126_From_freshwater_to_marine_aquaponic_new_opportunities_for_marine_fish_species_production.
48. Sterner. Stort potensiale i slam fra fiskeoppdrett sterneras.no: Sterner AS; 2017 [Available from: https://www.sterneras.no/2017/11/28/stort-potensiale-i-slam-fra-fiskeoppdrett/.
49. Garg BK, Gupta, I.C. Salinity Tolerance in Plants: Methods, Mechanisms and Management. Jodhpur, India: Scientific Publishers; 2011. Available from: https://books.google.no/books?id=OwpgDwAAQBAJ.
50. Haifa-group. Crop Guide: Tomato Plant Nutrition Haifa-group.com: Haifa Group; [Available from: https://www.haifa-group.com/crop-guide/vegetables/tomato/crop-guide-tomato-plant-nutrition.
51. SFGATE. What Nutrients Do Tomato Plants Need? sfgate.com: SFGATE; [Available from: https://homeguides.sfgate.com/nutrients-tomato-plants-need-40145.html.
52. Gonzales JA, Maruo, T., Shinohara,Y. UPTAKE ABILITY OF TOMATO PLANTS (SOLANUM LYCOPERSICUM L.) GROWN USING NUTRIENT FILM TECHNIQUE (NFT) BY ASCENDING NUTRIENT CONCENTRATION METHOD2010 [cited Semantic Scholar. Available from: https://www.semanticscholar.org/paper/UPTAKE-ABILITY-OF-TOMATO-PLANTS-(SOLANUM-L.)-GROWN-Gonzales-Maruo/8b3170c51e6b33b199990adb8764f84dc81c9837.
53. Barkla B. Warrigal greens are tasty, salty, and covered in tiny balloon-like hairs The Conversation2019 [updated 23.02.2019. Associate Professor of Plant Protein Biochemistry, Southern Cross University]. Available from: https://theconversation.com/warrigal-greens-are-tasty-salty-and-covered-in-tiny-balloon-like-hairs-112307.
54. Neves MA, Miguel, M., Marques, C., Panagopoulos, T., Beltrão, J. Tetragonia tetragonioides - a potencial salt removing species2007. Available from: https://www.researchgate.net/publication/237211942_Tetragonia_tetragonioides_-_a_potential_salt_removing_species_Response_to_the_combined_effects_of_salts_and_calcium.
55. Ahmed AK, Johnson, K. A. The effect of the ammonium: nitrate nitrogen ratio, total nitrogen, salinity (NaCl) and calcium on the oxalate levels of Tetragonia tetragonioides Pallas. Kunz. The Journal of Horticultural Science and Biotechnology [Internet]. 2000 2000/01/01; 75(5):[533-8 pp.]. Available from: https://doi.org/10.1080/14620316.2000.11511280.
56. Yousif B, Nt, N., Fukuda, Y., Hakata, H., Okamoto, Y., Masaoka, Y., Saneoka, H.,. Effect of Salinity on Growth, Mineral Composition, Photosynthesis and Water Relations of Two Vegetable Crops; New Zealand Spinach (Tetragonia …. INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY [Internet]. 2010 01.01.2020:[1560-8530 pp.]. Available from: https://www.researchgate.net/publication/228653139_Effect_of_Salinity_on_Growth_Mineral_Composition_Photosynthesis_and_Water_Relations_of_Two_Vegetable_Crops_New_Zealand_Spinach_Tetragonia.
57. Rocha M, M. New Zealand Spinach. In: assignment) Swotb, editor. Personal communication 2020.
58. Nelson Garden. Tomat, Potte-
'Balkonzauber' Nelson Garden: Nelson Garden; [Available from: https://www.nelsongarden.no/nor/nok/p/grnnsaker_120/tomat-potte-_91576.
59. Ferenhof E. New Zealand Spinach. In: assignment) Swotb, editor. Personal communication2020.

60. Albert S. HOW TO GROW NEW ZEALAND SPINACH Harvest to Table: Harvesttotable.com; 2020 [Available from: https://harvesttotable.com/how_to_grow_new_zealand_spinac/.
61. Robinson P. How much light do my indoor plants needs? Foundation Guides, Popilar, Technical Guides: Plantmaid; 2018 [Available from: https://www.plantmaid.com/how-much-light-do-my-indoor-plants-needs/.
62. Allen S. Aquarium Information, Reviews and more in an updated compiled format, especially in the subject of aquatic lighting aquarium-digest.com: Aquarium Article Digest; 2019 [Available from: https://aquarium-digest.com/tag/lighting-requirements-of-tomato-plant/.
63. Go Green Aquaponics. Gogrennaquaponics.com: Go Green Aquaponics. 2019. [cited 2020]. Available from: https://gogreenaquaponics.com/blogs/news/nutrient-film-technique-in-aquaponics.
64. Tuene S. Temperatures for the plant. In: assignment) Swotb, editor. Personal communication2020.
65. Grimwade A. What is the lifespan of a tomato plant and how can this be increased? Quora 2017 [updated 09.01.2020. Available from: https://www.quora.com/What-is-the-lifespan-of-a-tomato-plant-and-how-can-this-be-increased.
66. Delp R. Tomato Plant Development SFGATE: SFGATE; 2018 [Available from: https://homeguides.sfgate.com/tomato-plant-development-56092.html.
67. Bond D. How to Prevent Your Plants from Getting Nutrient Burn Maximum Yield: Maximum Yield; 2017 [Available from: https://www.maximumyield.com/how-to-prevent-your-plants-from-getting-nutrient-burn/2/3528.
68. Home Hydro Systems. N.F.T. (Nutrient Film Technique) System Homehydrosystems.com [Available from: http://www.homehydrosystems.com/hydroponic-systems/nft_systems.html.
69. Bastlová D, Květ, J. Differences in dry weight partitioning and flowering phenology between native and non-native plants of purple loosestrife (Lythrum salicaria L.). Flora - Morphology, Distribution, Functional Ecology of Plants [Internet]. 2002 2002/01/01/; 197(5):[332-40 pp.]. Available from: http://www.sciencedirect.com/science/article/pii/S036725300470033X.
70. Lærd statistics. One-way ANOVA in SPSS Statistics statistics.laerd.com [Available from: https://statistics.laerd.com/spss-tutorials/one-way-anova-using-spss-statistics.php.
71. How to Measure Growth Rate of Plants [Internet]. wikiHow. 2020. Available from: https://www.wikihow.com/Measure-Growth-Rate-of-Plants#References.
72. Baras T. DIY Hydroponic Gardens - How to Design and Build. 2018 [cited 06.07.2020]. In: DIY Hydroponic Gardens [Internet]. Minneapolis, USA: Cool Springs Press, Quarto Publishing Group USA, [cited 06.07.2020]. Available from: https://books.google.no/books?id=IpNVDwAAQBAJ&pg=PA184&lpg=PA184&dq=new+zealand+spinach+hydroponics+temperature&source=bl&ots=ea6vxsDxA2&sig=ACfU3U1Yu_z5Qn7Mbrjj5hdRhxL1SqDqGA&hl=no&sa=X&ved=2ahUKEwivhc-7u7jqAhVipYsKHaWUAMEQ6AEwGHoECAoQAQ#v=onepage&q=new%20zealand%20spinach%20hydroponics%20temperature&f=false.
73. Terejo-Tellez LI, Gomez-Merino, F. C. Nutrient Solutions for Hydroponic Systems. 2012 [cited 06.07.2020]. In: Hydroponics - A Standard Methodology for Plant Biological Researches [Internet]. Rijeka, Croatia: InTech, [cited 06.07.2020]. Available from: https://books.google.no/books?hl=no&lr=&id=otCcDwAAQBAJ&oi=fnd&pg=PA1&dq=hydroponics+temperature+affecting+plants&ots=BeDhGueYYW&sig=CFRvWKNDCSkLJTlMEN1o9q7iQSA&redir_esc=y#v=onepage&q=hydroponics%20temperature%20affecting%20plants&f=false.

74. Spengler T. Hydroponic Water Temperature: What Is The Ideal Water Temp For Hydroponics Gardening know how2018 [Available from: https://www.gardeningknowhow.com/special/containers/hydroponic-water-temperature.htm.
75. Stout M. Aquaponic Gardening 2013 [Available from: https://books.google.no/books?id=BIfEfqS8iKcC&lpg=RA1-PT74&ots=Wk4wUc5iY4&dq=aquaponics%20particles%20on%20roots&hl=no&pg=RA1-PT74#v=onepage&q=aquaponics%20particles%20on%20roots&f=false.
76. Hajiboland R, Aliasgharzadeh, N., Laiegh, S. F., Poschenrieder, C. Colonization with arbuscular mycorrhizal fungi improves salinity tolerance of tomato (Solanum lycopersicum L.) plants. Plant and Soil. 2010;331(1):313-27.
77. Zhang P, Senge, M., Dai, Y. EFFECTS OF SALINITY STRESS ON GROWTH, YIELD, FRUIT QUALITY AND WATER USE EFFICIENCY OF TOMATO UNDER HYDROPONICS SYSTEM. Reviews in Agricultural Science [Internet]. 2016; 4:[46-55 pp.]. Available from: https://www.researchgate.net/publication/310816079_Effects_of_salinity_stress_on_growth_yield_fruit_quality_and_water_use_efficiency_of_tomato_under_hydroponics_system.

# 7. Appendix

## Appendix 1 – Types of aquaponics

Types of set ups of aquaponics system

Media bed
This is the mostly used for a small-scale set up, for example in a back yard. An aquaponics system set up as a media bed requires three main components; A fish tank, a sump, a plant growing area and a water pump. This method is the easiest set up for beginners as the plants growing area is filled with medium functioning as both a mechanical and a biological filter. The water runs from the fish tank to the plants with the help of gravity, then it is pumped back into the fish tank. It is possible to use a flood- and-drain technique or keep a continuous water flow (29).

This set up can be done at a low cost and in many different ways. Also, a variety of materials can be used. The downside to this method is; the high weight, the high-water evaporation (if placed in the sun), the need for a medium and the possibility for the medium to clog. It is also less suitable in commercial production as it would be expensive when scaled up (29).

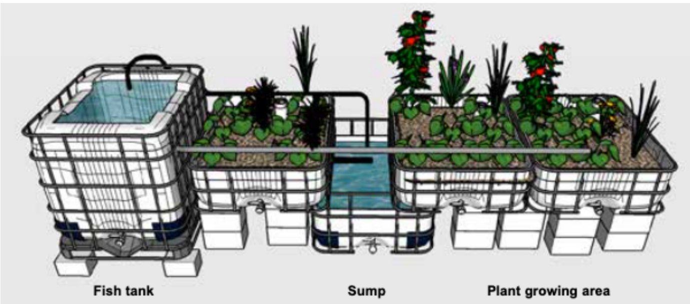



*Illustration of a small media bed unit (29).*

Nutrient film technique (NFT)
This method uses pipes, with holes, that are set up in a horizontal position. The water flows in one direction, usually with the help of gravitation. The water flowing in a thin film though the pipes is nutrient rich. The plants are put in net pots and placed in the holes in the pipes. This way the roots of the plant can absorb nutrient from the steady stream (29).

The NFT method is more used in commercial production as it is cheaper to scale up, compared to the media bed method. In addition, the evaporation is less significant as the system is closed. If building an aquaponics system in urban areas, on roof tops or small spaces, the NFT method might be the most suited. This because it can be built vertically and take up a small amount of floor space. As well as it has a relatively low weight, compared to the other two methods (29).

The NFT system and the deep-water culture system is more advanced than the media bed as it utilizes extra filtration systems. Both a unit for mechanic filter (to remove solids) and a biofilter (for nitrification) needs to be added to the setup (29).

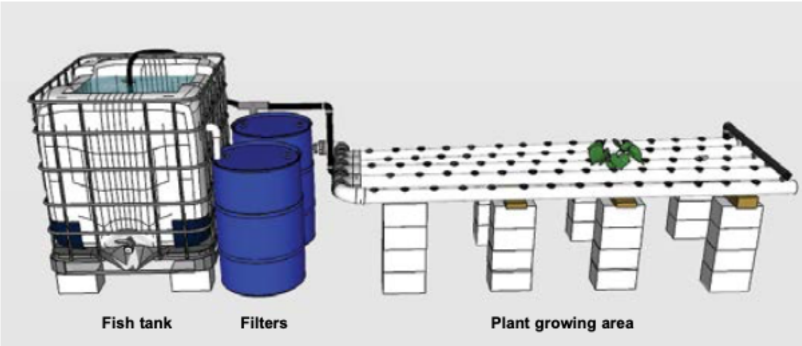



*Illustration of a small nutrient film technique unit (29).*

Deep water culture

The method of deep-water culture (DWC) is often used in commercial productions. The most common way this is done, is efficiently growing one specific type of crops, for example lettuce. Here the plants float on top of the water, with the help of a floating sheet. The roots are constantly floating in the nutrient rich water underneath. Water is pumped to one side of the system, and with help from gravitation, it flows back to the filters and then the fish tank. As mentioned under the section about NFT, the DWC also requires a more advanced filtration system (29).

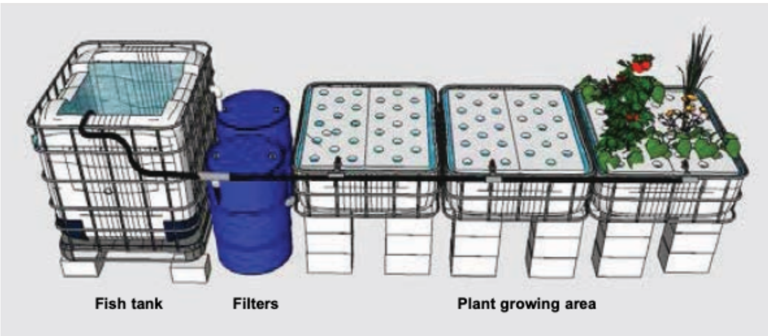



Illustration of a small deep-water culture unit (29).

## Appendix 2 – Researchers on Marine Aquaponics

An example of a successful marine aquaponics system is Boxman and her team who grew red drum together with sea purslane and saltwort. The fish thrived in the system, with a survival rate of 98 percent. The sea purslane also grew at a fast rate, while the saltwort did not at first, but after five months the growth started improving (40).

Another example is from the University of Tuscia in Italy. Here they grew salsola (in a floating system) and sea asparagus (on sand beds) together with European seabass. The result from the trail was that both plants grew similarly or better than the control group, which grew in a chemically fertilized hydroponics system. It was found that the plants grew fairly well under salinities up to a maximum of 20 ppt, at higher rates the plants decreased (41).

Appendix 3 – Analysis report

# Analyserapport

Moss

Eurofins Agro Testing Norway AS
Postboks 3033
NO-1506 Moss
+47 09450
www.eurofins.no

| | | | | |
|---|---|---|---|---|
| Kundenummer | | Prøvemottak | 15.02.2017 | Side 1 (1) |
| Prøvetype | Gjødselprøver | Analyserapport klar | 06.03.2017 | |
| Oppdragsmarking | Tørka smolt-slam | | | |

Lab.nr. JON004789-17
Sted for prøvetaking
Tatt ut 13.02.2017
Merket Marine Harvest avd. Steinsvik

| Parameter | Enhet | | Måleu. | Ref/Metode basert på | Lab |
|---|---|---|---|---|---|
| Tørrstoff | % | 80.3 | | Gravimetrisk | V |
| pH | | 5.53 | | | V |
| Ammonium-N (NH4-N) | kg/tonn | 5.2 | ±4% | EU 152/2009 Kje | V |
| Nitrogen (N) | kg/tonn | 45.4 | ±4% | EU 152/2009, mo | V |
| Svovel (S) | kg/tonn | 3.1 | ±20% | EN ISO 11885 | V |
| Fosfor (P) | kg/tonn | 20 | ±20% | EN ISO 11885 | V |
| Kalium (K) | kg/tonn | 1.2 | ±20% | EN ISO 11885 | V |
| Magnesium (Mg) | kg/tonn | 2.3 | ±20% | EN ISO 11885 | V |
| Kalsium (Ca) | kg/tonn | 49 | ±20% | EN ISO 11885 | V |
| Natrium (Na) | kg/tonn | 1.5 | ±20% | EN ISO 11885 | V |
| C/N forhold | | 7.8 | | Beregning | V |
| Kobber (Cu) | mg/kg TS | 14 | ±20% | EN ISO 11885 | V |
| Sink (Zn) | mg/kg TS | 410 | ±20% | EN ISO 11885 | V |
| Bor (B) | mg/kg TS | 12 | ±20% | EN ISO 11885 | V |
| Mangan (Mn) | mg/kg TS | 150 | ±20% | EN ISO 11885 | V |
| Jern (Fe) | mg/kg TS | 560 | ±20% | EN ISO 11885 | V |
| Bly (Pb) | mg/kg TS | 0.50 | ±20% | EN ISO 17294m | V |
| Krom (Cr) | mg/kg TS | 2.9 | ±20% | EN ISO 17294m | V |
| Nikkel (Ni) | mg/kg TS | 1.0 | ±20% | EN ISO 17294m | V |
| Cadmium (Cd) | mg/kg TS | 0.60 | ±20% | EN ISO 17294m | V |
| Kvikksølv (Hg) | mg/kg TS | 0.068 | ±20% | EN ISO 17294m | V |
| Salmonella | | Ikke påvist /25g | | NMKL 71:1999 | V |
| Koliforme bakterie | cfu/g | <10 | | AOAC 991.14 | V |
| Escherichia coli | cfu/g | <10 | | AOAC 991.14 | V |
| Termotolerante coliforme bakterier | MPN/g | < 0.2 | | NMKL 96:2009 | V |
| Nitrit+Nitrat-N | mg/kg | 68 | ±10% | DS 230:1988 mod | V |
| Aske | % | 14.4 | | EU 152/2009 | V |
| Organisk innhold | % | 65.9 | | EU 152/2009 | V |
| Klorid Cl | % TS | 0.08 | | EU 71/250 mod | V |

# Appendix 4 – Nutrient requirements

Nutrient requirements for the species and nutrient content in waste product and hydroponic solution

| Nutrients | Tomato | | | | | Spinach | | Nutrients assimilated: Tomato 500g* | | Nutrients assimilated: Spinach 400g* | Dried fish waste used in the experiment | | | | | Hydroponic solution | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lower limit | Upper limit | Unit | | | Lower limit | Upper limit | | | | | Mixed FW with water | 20g FW/10l | | | | Mixed HS | 20ml/10l freshwater |
| Tot- N | 3-6 | % | 30,0 | 60,0 | g/kg | 1 | g/kg | 15 | 30 | 0,4 | 45,4 | g/kg | 4,54 % | 0,908 | g/10l | 4 | % | 40g/kg | 0,8 | g/10l |
| NO3 (nitrate-nitrogen) | | | | | | | | | | | | | | | | | | | | |
| Nitrit+nitrat-N | | | | | | | | | | | 0,068 | g/kg | | | | | | | | |
| (NH4-N) | | | | | | | | | | | 5,2 | g/kg | | | | | | | | |
| TOC | | | | | | | | | | | | | | | | | | | | |
| P | 0,3-0,8 | % | 3,0 | 8,0 | g/kg | 0,11 | g/kg | 1,5 | 4 | 0,044 | 20 | g/kg | 2 % | 0,4 | g/10l | 0,7 | % | 7g/kg | 0,14 | g/10l |
| P2O5 | | % | | | | | | | | | | | | | | | | | | |
| K | 2,5-5,0 | % | 25,0 | 50,0 | g/kg | 1 | g/kg | 12,5 | 25 | 0,4 | 1,2 | g/kg | | | | 3 | % | 30g/kg | 0,6 | g/10l |
| K2O | | | | | | | | | | | | | | | | | | | | |
| Ca | 2,0-6,0 | % | 20,0 | 60,0 | g/kg | 0,78 | g/kg | 10 | 30 | 0,312 | 49 | g/kg | | | | 1 | % | 10g/kg | 0,2 | g/10l |
| CaO | | | | | | | | | | | | | | | | | | | | |
| Mg | 0,5-1,0 | % | 5,0 | 10,0 | g/kg | 0,18 | g/kg | 2,5 | 5 | 0,072 | 2,3 | g/kg | | | | 0,3 | % | 1,2g/kg | 0,06 | g/10l |
| MgO | | | | | | | | | | | | | | | | | | | | |
| S | 0,5-0,9 | % | 5,0 | 9,0 | g/kg | 0,2 | g/kg | 2,5 | 4,5 | 0,08 | 3,1 | g/kg | | | | 0,3 | % | 1,2g/kg | 0,06 | g/10l |
| Na | 1,00 | % | 0,10 | | g/kg | | | 0,05 | 0 | | 1,5 | g/kg | | | | | | | | |
| B | 40-60 | ppm | 0,04 | 0,06 | g/kg | | | 0,02 | 0,03 | 0 | | | | | | 0,02 | % | 0,08g/kg | 0,004 | g/10l |
| B2O3 | | | | | | | | | | | | | | | | | | | | |
| Cu | 8-20 | ppm | 0,01 | 0,02 | g/kg | | | 0,004 | 0,01 | 0 | 0,014 | g/kg | | | | 0,005 | % | 0,02g/kg | 0,001 | g/10l |
| Fe | 100-200 | ppm | 0,10 | 0,20 | g/kg | | | 0,05 | 0,1 | 0 | 0,56 | g/kg | | | | 0,05 | % | 0,2g/kg | 0,01 | g/10l |
| Mn | 100-200 | ppm | 0,10 | 0,20 | g/kg | | | 0,05 | 0,1 | 0 | 0,15 | g/kg | | | | 0,02 | % | 0,08g/kg | 0,004 | g/10l |
| MnO | | | | | | | | | | | | | | | | | | | | |
| Mo | | | | | | | | | | | | | | | | 0,003 | % | 0,012g/kg | 0,0006 | g/10l |
| Zn | 35-50 | ppm | 0,04 | 0,05 | g/kg | | | 0,0175 | 0,025 | 0 | 0,41 | g/kg | | | | 0,03 | % | 0,12g/kg | 0,006 | g/10l |

*Expected growth during test period

References:

| | |
|---|---|
| Tomato plants | Haifa |
| Spinach | Furlani, 2009 |
| Spinach nutrient solution | Yousif, 2010 |
| Dried fishwaste used in experiment | Eurofins, 2017 |
| Hydroponic solution | Nelson Garden |

## Appendix 5 – Criteria for the System

Criteria for the system
To test the set hypothesizes the structure had to be built in regard to these requirements:

- Hydroponic/aquaponic solution.
- Can contain enough plants to get a statistical answer.
- Can contain two different species irrigated with same parallels of water.
- Containers suited for netpots.
- Can fit in a greenhouse.
- Cheap materials that are easy to get a hold of.
- Low cost.
- A system that does not need maintenance 24/7, but appx. 1-2 times a day during the trial.
- Easy to maintain.
- The system can run for 30 days minimum.
- Space for plants to grow for 30 days.
- Provides the plant with sufficient nutrients.
- Plant roots can reach the water.
- Water flows continuously.
- Pumps water.
- Water flow must be suitable for the plants.
- Plants get enough light.
- Water does not evaporate at a big scale.
- Takes advantage of gravity.
- Space for 10 plants in each pipe. 8 Pipes.
- Both species can be in the same parallel of water.

## Appendix 6 – Materials

Materials

For the structure:

3 x 3m white PVC pipes Ø75mm

4 x blue buckets 10l + lids

4 x red buckets 10l + lids

4 x wooden planks 40cm

4x plastic containers for sodas

1 x Ikea Förhöja Bench

1 x garden hose

1 x hole saw Ø5cm

5 x water pump

15 x 1m water hose 13mm

Bubble wrapper

1 x duct tape

100 x plastic strips

80 x net pots

Leca

Kitchen weight

Fan oven

To germinate and grow the plants:

2 x plastic boxes 6l(?)

1 x bag of soil

1 x bag of sand

1 x bag of New Zealand spinach seeds

1 x bag of balkonzauber tomato seeds

Cling film

Gravel

3 x Grow lamp

Same equipment used for soil plants.

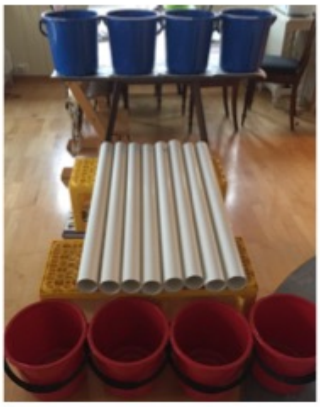
Dried fish waste

Salt

# Appendix 7 – Pictures of the Building Process

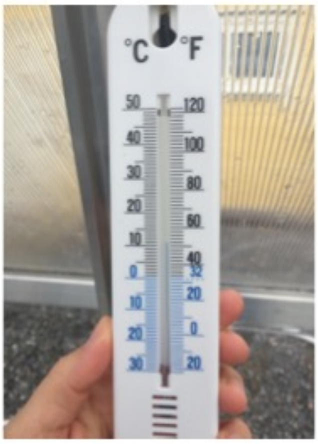




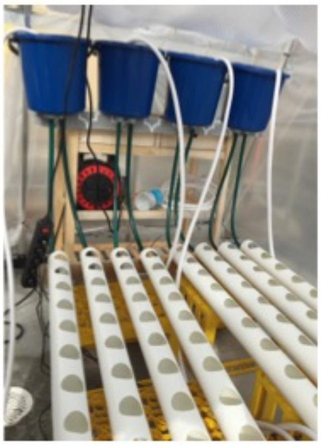













## Appendix 8 – Hydroponic Solution

| Næringsstoff | Hydroponisk næring |
|---|---|
| Totalt nitrogen (N) | 4% (hvorav nitratnitrogen 3,6% og ammoniumnitrogen 0,4%.) |
| Fosfor (P) | Vannløselig 0,7% |
| Kalium (K) | Vannløselig 3% |
| Kalsium (Ca) | 1 % |
| Magnesium (Mg) | 0,30 % |
| Svovel (S) | 0,30 % |
| Bor (B) | 0,02 % |
| Kobber (Cu)* | 0,01 % |
| Jern (Fe)* | 0,05 % |
| Mangan (Mn)* | 0,02 % |
| Molybden (Mo)* | 0,00 % |
| Zink (Zn)* | 0,03 % |

Oppløsning av uorganisk gjødsel NPK 4-0. 7-3 med mikronæringsstoffer.
Nelson Garden AS
https://www.gartnerbutikken.no/products/hydroponisk-naring-250-ml?gclid=EAIaIQobChMIiK_sovDn6AIVg7UYCh2MzAJjEAQYAiABEgJ4OvD_BwE


## Appendix 9 – Calculations on Nutrients to add

| Calculations on waste product to add to secure sufficient nitrogen levels for the plant | | |
|---|---|---|
| Content of N in tomato plants | 50 | g/kg |
| Total weight of 9 start plants | 20 | g |
| Average growth per day (5.5% daily growth gives appx. the double weight in two weeks) | 5,5 | % |
| Alternative: Growth per two weeks | 100 | % |
| Number of days from start until finish | 28 | daysr |
| | | |
| Days until next water change | 7 | |
| | | |
| Content of N in the waste product | 45 | g/kg |
| Added waste product at water change (once a week) | 15 | g |
| Added waste product (daily in addition to at water changes) | 10 | g |

| Calculations to secure sufficient levels of nitrogen (N) throught the experiment | | |
|---|---|---|
| Waste products are added once a week at water change, in addition to once daily. The remaining N is removed at water change. | | |
| | | |
| Total amount N utilized by plants | 3,5 | g |
| Total amount N added | 15,3 | g |
| Remaining N at the first water change (and N utilized by plants) [g] | 3,4 | 0,5 |
| Remaining N at the second water change (and N utilized by plants) [g] | 3,2 | 0,7 |
| Remaining N at the third water change (and N utilized by plants) [g] | 2,9 | 1,0 |
| Remaining N at the end of the experiment (and N utilized by plants) [g] | 2,4 | 1,4 |
| N added minus N utilized by plants | 11,8 | g |

## Appendix 10 – Documentation of state of plants

Dato: 27/4 (kl. 17.00)

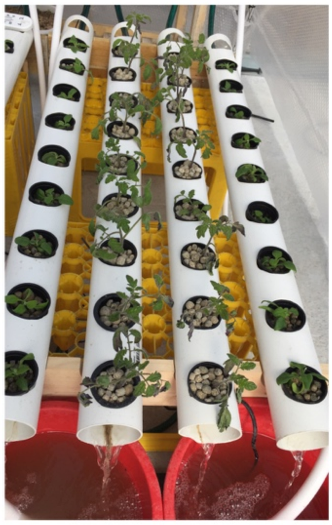
| Parallell | Temp 20°C | Kommentar | Kommentar2 |
|---|---|---|---|
| | Vanntemp °C: | Tomat - Ser ut som de ikke takler overgangen. Grenene henger ned på rørene. | Spinat (ikke satt ut) |
| 1 | 21,8 | Henger litt med hodet. | |
| 2 | 21,4 | Ser ut som de ikke takler overgangen. Grenene henger ned på rørene. | |
| 3 | 21,6 | Ser ut som de ikke takler overgangen. Grenene henger ned på rørene. | |
| 4 | 22 | Ser ut som de ikke takler overgangen. Grenene henger ned på rørene. | |
| 5 (Soil) | | Ser fin ut. | |
| Tiltak: | | Se hvordan det går. Kontrollere at vanntemperaturen holder seg over 15°C til kvelden og natten. Ovn skrudd på. | |




Dato: 28/4 (kl.10.00)

| Parallell | Temp | Kommentar | Kolonne1 |
|---|---|---|---|
| | 08.00 – 18,6°C<br>11.30 - 26°C<br>14.00 - 23°C | | |
| | Vanntemp °C: | Tomat - Tomatene har generelt komt seg, og henger ikke så mye med hodet. | Spinaten ble satt ut i systemet. Alle ser fin ut. |
| 1 | 22 | Litt slapp, ellers fin | |
| 2 | 23,5 | Tørre blader | |
| 3 | 24,9 | Tørre blader | |
| 4 | 25,6 | Tørre blader | |
| 5 (Soil) | | Litt slapp, men ser fin ut | |
| Tiltak: | | Se an til i morgen | |



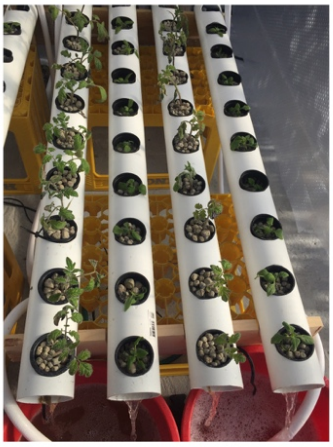
Dato: 29/4 (kl.12.00)

| Parallell | Temp | Kommentar | Kommentar2 |
|---|---|---|---|
| | 08.00 – 16,4°C<br>11.00 – 21,6°C | | |
| | Vanntemp °C: | Tomat | Spinat |
| 1 | 20,3 | Fine planter. Noen er litt gul på bladene. Fine røtter. | Litt slappe planter. |
| 2 | 19,8 | Plantene har komt seg etter flytting, men 2 planter har slappe og tørre blad. Slim/partikler på røttene. | Litt slappe planter. Skum i vannet i parallellen. |
| 3 | 20 | Plantene har komt seg etter flytting, men 8 planter har slappe og tørre blad. Slim/partikler på røttene. | Litt slappe planter. |
| 4 | 21,3 | Plantene har komt seg etter flytting, men alle plantene har slappe og tørre blad. Slim/partikler på røttene. | Litt slappe planter. Skum i vannet i parallellen. |
| 5 (Soil) | | Litt slappe planter, men ellers ser de bra ut. | Litt slappe planter, men ellers ser de bra ut. |
| Tiltak | Ok temperatur | Klipp av tørre grener, de er død og det kan påvirke planten negativt om de ikke fjernes. | Ingen tiltak. |




Dato: 30/4 (kl. 09.00)

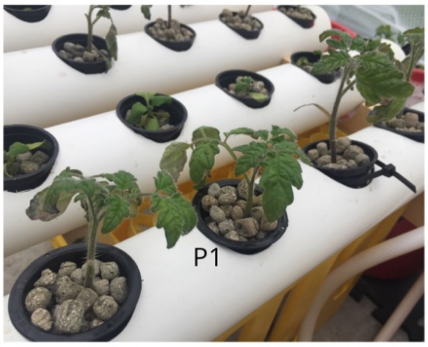
| Parallell | Temp 20,6 | Kommentar | Kommentar2 |
|---|---|---|---|
| | Vanntemp °C | Tomat | Spinat |
| 1 | 19,1 | Noen planter har litt tørre blader. Kan det være fordi varmeovnen er nærmest disse plantene? Lite vann i bøtta | Fortsatt litt slapp i bladene, men ser ut til å klare seg fint. Gjelder alle. |
| 2 | 18,4 | Lite vann i bøtta | |
| 3 | 17,7 | Lite vann i bøtta | |
| 4 | 17,7 | Lite vann i bøtta | |
| 5 (Soil) | | Tørr jord | |
| Tiltak: | | Fyll på vann i bøttene og vann jordplanter. Tilsetter 10 g fiskeslam og riktig mengde salt på parallell 2, 3 og 4. 10 g fiskeslam skal tilsettes hver dag det ikke er vannskifte, fra i dag av. | |

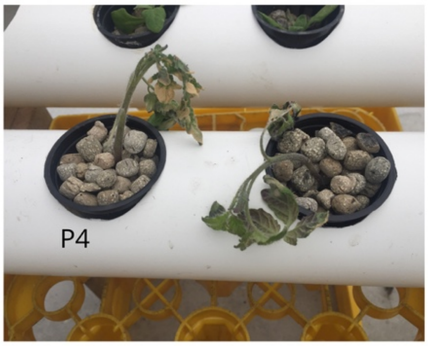


Dato: 1/5 (kl. 14.00)

| Parallell | Temperatur | Kommentar | Kommentar2 |
|---|---|---|---|
| | 18°C | Ser ikke bra ut for parallell 4 tomat. | |
| | Vanntemp °C | Tomat | Spinat |
| 1 | 17,3 | Ser bra ut, noen tørre blader. | 1 plante hvor røttene ikke var i vannet. |

| | | | |
|---|---|---|---|
| 2 | 17,3 | Noen blad er litt slapp. | En slapp spinat. |
| 3 | 17,9 | Ser ok ut, noen slappe og tørre blader. | Litt slapp. |
| 4 | 18 | Ser ikke lovende ut. Veldig tørre planter. De vil trolig dø. | Ser ok ut, litt slapp. |
| 5 (Soil) | | Ser bra ut. | Ser bra ut. |
| Tiltak: | Varme på | Daglig næring tilsatt. | Passet på at røtter når næring. |













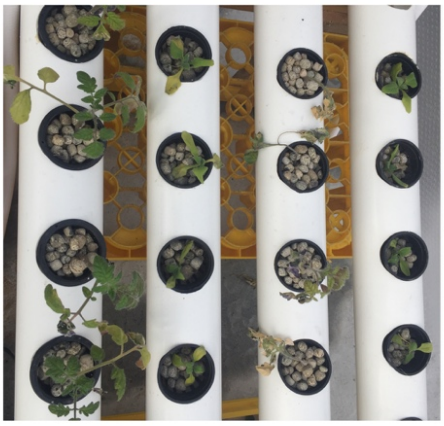

Dato: 2/5 (kl.10.00)

| Parallell | Temp | Kommentar | Kommentar2 |
| --- | --- | --- | --- |
| | Vanntemp °C | Tomat | Spinat |
| 1 | 17,2 | Planter ser bra ut og vokser. Røtter er rene og vokser. | Noen av plantene er litt slapp og noen blad er gul. Ellers ser de bra ut. |
| 2 | 17 | Står fint, noen grener er litt slapp og noen blad litt flekkete, ellers ser det ut som den har det bra. | Slappe planter. Noen av røttene når ikke vannet. Snudd plantene slik at alle når vannet. |
| 3 | 16,8 | Lekkasje, nesten alt vann rent ut. Nytt vann blandet. Ser ok ut, noen grener er litt slapp. | Planter litt slapp, noen gule blader. |
| 4 | 16,8 | Veldig slapp og de fleste ligger på røret. | Noen blad er litt brun. |
| 5 (Soil) | | Fuktig jord. Planter ser bra ut. | Fuktig jord. Planter ser bra ut. |
| Tiltak: | Daglig påfyll av næring. | | Snudd på spinatplanter og sikret at alle har nok røtter i vannet. |



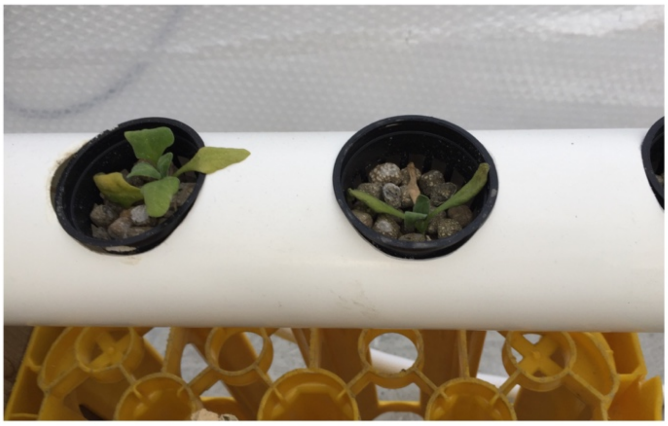

Dato: 3/5 (kl.10.00)

| Parallell | Temp | Kommentar | Kommentar2 |
| --- | --- | --- | --- |
| | Vanntemp °C | Tomat | Spinat |
| 1 | 15,6 | Trives. | Ser bedre ut enn de andre parallellene. |
| 2 | 15,4 | Ingen merkbar forandring. | Ingen forandring. Røttene er i vann. |
| 3 | 15,4 | Ingen merkbar forandring. | Noen med slappe og gule blader. |
| 4 | 15,3 | Ser dårlig ut. | Begynner å tape seg. Mange med slappe og gule blad. |
| 5 (Soil) | | To planter er litt gul på noen blad. | En plante med noen gule blad. |
| Tiltak: | | | |


Dato: 4/5 (kl.10.00)

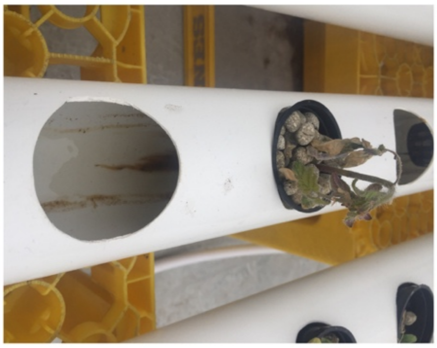
| Parallell | Temp | Kommentar | Kommentar2 |
|---|---|---|---|
| | Vanntemp °C | Tomat | Spinat |
| 1 | 16,5 | Trives. | Ok. |
| 2 | 16,3 | Ikke mye forandring. | Gule blader. |
| 3 | 16 | Ikke mye forandring. | Ser ikke så bra ut. Mange slappe og gule blad. |
| 4 | 16,1 | Flere døde tomatplanter. | Slappe. |
| 5 (Soil) | | Ingen endring. | Ingen endring. |
| Tiltak: | Vannskifte. | Døde tomatplanter fjernes. | |

Dato: 5/5 (kl.10.00)

| Parallell | Temp | Kommentar | Kommentar2 |
|---|---|---|---|
| | Vanntemp °C | Tomat | Spinat |
| 1 | 17 | Fin vekst. Flere nye blader siden de ble satt i systemet. Fin grønn farge. | Mange av plantene er fine og grønne. De vokser, men noen av de nederste av bladene er gule. |
| 2 | 16,5 | Ikke særlig mye vekst. Muligens litt. Plantene er mørkere enn i P1. Ser ut som de skadede bladene hovedsakelig er de som ble «ødelagt» etter sjokket av flyttingen. Kanskje planten kommer seg. | 3 av plantene ser død ut. 1 fjernet. 5 ser ok ut. Den siste kan gå begge veier? |
| 3 | 16 | Noen slappe grener. Kanskje lurt å fjerne og se om veksten øker. Øverste grener ser bra ut og det er trolig vekst. Planten bruker kanskje unødvendig energi på å prøve å reparere ødelagte/døde grener. | 2 planter er så god som døde. Noen ser ut til å vokse greit. Mye gule blader, men plantene kan kanskje komme seg likevel. |
| 4 | 16 | De fleste plantene ser døde ut. 5 ligger bare på røret, mens de 4 andre står så vidt enda. | Noen ser veldig slapp ut, men ingen er inntørket og derfor blir de stående. Noen ser ut til å greie seg. |
| 5 (Soil) | | Ingen forandring annet enn litt vekst. | Ingen forandring. |
| Tiltak: | | 5 tomatplanter fjernet P4. Klipt av døde grener for å se om dette kan redde noen av plantene. | 1 død spinat fjernet P2. |





Dato: 8/5 (kl.15.00)

| Parallell | Temp | Kommentar | Kommentar2 |
|---|---|---|---|
| | Vanntemp °C | Tomat | Spinat |
| 1 | 22,1 | Vannslangen til pumpen hadde hoppet av slik at vannet ikke strømmet gjennom rørene. Tomatplantene dehydrert etter noen få timer uten næring. Ellers vokser de veldig bra, de er dobbelt så stor som de andre plantene. | Ikke like påvirket av mangel på næring. De vokser fint og er både større og grønnere enn i andre paralleller. |
| 2 | 22,3 | Ser ut til å ha komt seg og vokser sakte. | To av plantene er antakeligvis død. De andre ser ut til å vokse. |
| 3 | 22,2 | Vokser sakte. Har noen blader som er slapp, men ellers bedre enn forventet. | Tre planter er antakeligvis død, resten vokser sakte. |
| 4 | 22 | De 4 tomatplantene som er igjen kommer nok til å dø. En av de har fortsatt litt grønne blader, så de får stå litt lenger. | Mange døde blader. Men det ser ut til at alle plantene lever. Lite vekst. |
| 5 (Soil) | | Ser grei ut. Mer vekst enn hos P 2,3 og 4. Litt gule blader. | Vokser god. Grønne og fine blader. |
| Tiltak: | | Sette på igjen slange P1. Følge med på at de kommer seg igjen. Fjerne døde blader og grener. | |

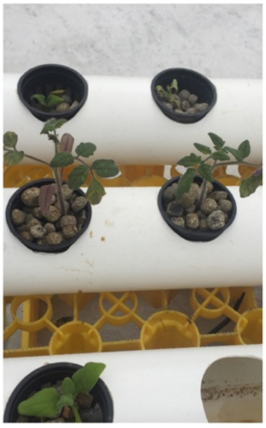




Dato: 13/5 (kl.10.00)

| Parallell | Temp 19,3°C | Kommentar | Kommentar2 |
|---|---|---|---|
| | Vanntemp °C | Tomat | Spinat |

| | | | |
|---|---|---|---|
| 1 | 20,5 | Plantene vokser godt. Fin grønnfarge. De begynner å utvikle blomsterknopper. Røttene er store og friske. | Vokser godt. Et par planter er betydelig større enn de andre. Disse er veldig store og røttene er godt utviklet. Resten av plantene er litt mindre, men ser fine ut. |
| 2 | 21,2 | Plantene ser fin ut, men er mye mindre enn de i parallell 1. Røttene er full av slim, men det har begynt å utvikle seg mer nye røtter. | En plante er helt tørr. Denne fjernes (nr.7). Nr 5 har mange tørre blader, men to små grønne i midten. Den får stå. De andre plantene ser ok ut, men har noen gule blader. Røttene er nokså tynne og dekt i slim. |
| 3 | 21,3 | Plantene ser litt spinkle ut da de ikke har fått særlig mye ny vekst etter fjerning av døde grener. De lever og er grønn, men ser ikke ut til å ha det optimalt. Mye slim på røtter. | 3 av spinatene er død. Disse fjernes (nr 3,7 og 8). Resten av plantene er små, og har noen gule blader. Men de lever og vokser sakte. Slim på røtter. |
| 4 | 23 | Alle tomatplanter er døde. De siste 4 fjernes i dag. | Lite vekst, men alle er i live til en viss grad, så ingen fjernes. |
| 5 (Soil) | | Ser bra ut. | Ser bra ut. |
| Tiltak: | Varmeovn flyttes til motsatt side av drivhus for å se om mer bevegelse i lufta kan påvirke plantene. Letter på bobleplasten i bakkant. | Fjern alle tomater P4. 7 nye tomatplanter settes i P4 for å se om disse oppnår noe forskjell og slik at røret ikke bare står tomt. Lengde på alle planter måles. Slim fra røtter ble fjernet etter måling. | Fjern døde spinat P2 og P3. Døde blader fjernes. |

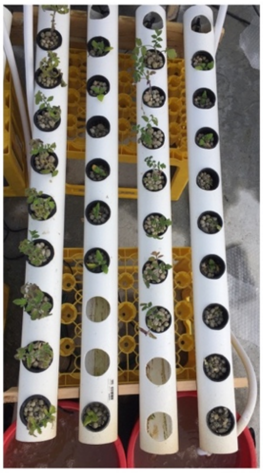




Dato: 18/5 (kl. 10.00)

| Parallell | Temp 10°C | Kommentar | Kommentar2 |
|---|---|---|---|
| | Vanntemp °C | Tomat | Spinat |
| 1 | 15,4 | Utrolig god vekst og fin farge. Det begynner å bli litt trangt for plantene. | Veldig god vekst. Men blir skygget av tomatplanten. |
| 2 | 15,6 | Grønne og fine planter, men vokser sent. | Alle plantene har noen gule blader. Plante nr. 5 er antakeligvis død. |
| 3 | 15,9 | Alle lever, men de ser fortsatt litt stusselig ut. Vokser sent. | Vokser veldig sakte. Noen gule blad. |
| 4 | 16,1 | De nye tomatene ser ut til å greie seg fint. Ingen tegn til sjokk etter flytting. Kanskje fordi disse var hydroponisk fra før? | 4/9 av planterne er fortsatt i livet. De andre nærmer seg død. |

| | | | |
|---|---|---|---|
| | | | Venter noen dager til for å være sikker, før de fjernes. |
| 5 (Soil) | | To av plantene er store og fine. De to andre er vesentlig mindre. Noen gule og tørre blad. | Vokser fint. Bedre enn p2-4, men mindre enn p1. |
| Tiltak: | | Strømmen hadde gått, derfor var temperaturen i drivhuset lavere enn ønsket. Ny strømkabel lagt. Vannbytte på alle paralleller. | |


Dato: 22/5 (kl.10.00)

| Parallell | Temp 20°C | Kommentar | Kommentar2 |
|---|---|---|---|
| | Vanntemp °C | Tomat | Spinat |
| 1 | 19,3 | Blomstring på flere av plantene. | Fortsetter med god vekst. |
| 2 | 19,1 | Ikke særlig utvikling, bare sakte vekst. | Ingen endring. Plante nr. 5 er nok død, men kan stå til eksperimentet er ferdig. |
| 3 | 19,2 | Ikke særlig forandring. | Ikke særlig forandring. |
| 4 | 19,1 | De nye plantene som er satt inn er nesten død. | 4 døde planter fjernes. En annen plante er antakeligvis død, men får stå litt til. |
| 5 (Soil) | | Ikke særlig forandring. | Ikke særlig forandring. |
| Tiltak: | Åpne vinduer og dører. | | |

## Appendix 11 – ANOVA Results Weight

One Way Anova for parallels of tomato plants

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | Minimum | |
|---|---|---|---|---|---|---|---|---|---|
| Start_weight | 1.00 | 9 | 2.6667 | 1.00000 | .33333 | 1.8980 | 3.4353 | 2.00 | |
| | 2.00 | 9 | 2.3889 | .99303 | .33101 | 1.6256 | 3.1522 | .50 | |
| | 3.00 | 9 | 2.8333 | 1.06066 | .35355 | 2.0180 | 3.6486 | .50 | |
| | 4.00 | 9 | 2.0556 | .72648 | .24216 | 1.4971 | 2.6140 | .50 | |
| | 5.00 | 4 | 2.4000 | .00000 | .00000 | 2.4000 | 2.4000 | 2.40 | |
| | Total | 40 | 2.4775 | .90963 | .14383 | 2.1866 | 2.7684 | .50 | |
| End_weight | 1.00 | 9 | 88.8333 | 56.27155 | 18.75718 | 45.5792 | 132.0875 | 13.80 | |
| | 2.00 | 9 | 10.4111 | 1.58307 | .52769 | 9.1943 | 11.6280 | 8.00 | |
| | 3.00 | 9 | 3.0111 | .93467 | .31156 | 2.2927 | 3.7296 | 1.50 | |
| | 4.00 | 9 | .0000 | .00000 | .00000 | .0000 | .0000 | .00 | |
| | 5.00 | 4 | 21.7250 | 10.36255 | 5.18128 | 5.2359 | 38.2141 | 9.90 | |
| | Total | 40 | 25.1800 | 43.64397 | 6.90072 | 11.2220 | 39.1380 | .00 | |
| Dry_weight | 1.00 | 9 | 10.2301 | 6.87414 | 2.29138 | 4.9462 | 15.5140 | 1.56 | |
| | 2.00 | 9 | 1.1097 | .15418 | .05139 | .9912 | 1.2283 | .83 | |
| | 3.00 | 9 | .3650 | .10167 | .03389 | .2868 | .4431 | .20 | |
| | 4.00 | 9 | .0000 | .00000 | .00000 | .0000 | .0000 | .00 | |
| | 5.00 | 4 | 2.3850 | 1.06385 | .53192 | .6922 | 4.0778 | 1.04 | |
| | Total | 40 | 2.8721 | 5.13578 | .81204 | 1.2296 | 4.5146 | .00 | |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Start_weight | Between Groups | 3.159 | 4 | .790 | .949 | .447 |
| | Within Groups | 29.111 | 35 | .832 | | |
| | Total | 32.270 | 39 | | | |
| End_weight | Between Groups | 48605.979 | 4 | 12151.495 | 16.561 | .000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Within Groups | 25681.085 | 35 | 733.745 | | |
| | Total | 74287.064 | 39 | | | |
| Dry_weight | Between Groups | 646.976 | 4 | 161.744 | 14.831 | .000 |
| | Within Groups | 381.698 | 35 | 10.906 | | |
| | Total | 1028.674 | 39 | | | |

**Post Hoc Tests**

**Multiple Comparisons**

Tukey HSD

| Dependent Variable | (I) Parallel | (J) Parallel | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| Start_weight | 1.00 | 2.00 | .27778 | .42992 | .966 | -.9583 | 1.5138 |
| | | 3.00 | -.16667 | .42992 | .995 | -1.4027 | 1.0694 |
| | | 4.00 | .61111 | .42992 | .618 | -.6249 | 1.8472 |
| | | 5.00 | .26667 | .54804 | .988 | -1.3090 | 1.8423 |
| | 2.00 | 1.00 | -.27778 | .42992 | .966 | -1.5138 | .9583 |
| | | 3.00 | -.44444 | .42992 | .838 | -1.6805 | .7916 |
| | | 4.00 | .33333 | .42992 | .936 | -.9027 | 1.5694 |
| | | 5.00 | -.01111 | .54804 | 1.000 | -1.5868 | 1.5645 |
| | 3.00 | 1.00 | .16667 | .42992 | .995 | -1.0694 | 1.4027 |
| | | 2.00 | .44444 | .42992 | .838 | -.7916 | 1.6805 |
| | | 4.00 | .77778 | .42992 | .385 | -.4583 | 2.0138 |
| | | 5.00 | .43333 | .54804 | .932 | -1.1423 | 2.0090 |
| | 4.00 | 1.00 | -.61111 | .42992 | .618 | -1.8472 | .6249 |
| | | 2.00 | -.33333 | .42992 | .936 | -1.5694 | .9027 |
| | | 3.00 | -.77778 | .42992 | .385 | -2.0138 | .4583 |
| | | 5.00 | -.34444 | .54804 | .969 | -1.9201 | 1.2312 |
| | 5.00 | 1.00 | -.26667 | .54804 | .988 | -1.8423 | 1.3090 |
| | | 2.00 | .01111 | .54804 | 1.000 | -1.5645 | 1.5868 |
| | | 3.00 | -.43333 | .54804 | .932 | -2.0090 | 1.1423 |
| | | 4.00 | .34444 | .54804 | .969 | -1.2312 | 1.9201 |
| End_weight | 1.00 | 2.00 | 78.42222* | 12.76928 | .000 | 41.7098 | 115.1347 |
| | | 3.00 | 85.82222* | 12.76928 | .000 | 49.1098 | 122.5347 |
| | | 4.00 | 88.83333* | 12.76928 | .000 | 52.1209 | 125.5458 |
| | | 5.00 | 67.10833* | 16.27770 | .002 | 20.3090 | 113.9077 |
| | 2.00 | 1.00 | -78.42222* | 12.76928 | .000 | -115.1347 | -41.7098 |
| | | 3.00 | 7.40000 | 12.76928 | .977 | -29.3125 | 44.1125 |
| | | 4.00 | 10.41111 | 12.76928 | .924 | -26.3013 | 47.1236 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5.00 | -11.31389 | 16.27770 | .956 | -58.1133 | 35.4855 |
| | 3.00 | 1.00 | -85.82222* | 12.76928 | .000 | -122.5347 | -49.1098 |
| | | 2.00 | -7.40000 | 12.76928 | .977 | -44.1125 | 29.3125 |
| | | 4.00 | 3.01111 | 12.76928 | .999 | -33.7013 | 39.7236 |
| | | 5.00 | -18.71389 | 16.27770 | .779 | -65.5133 | 28.0855 |
| | 4.00 | 1.00 | -88.83333* | 12.76928 | .000 | -125.5458 | -52.1209 |
| | | 2.00 | -10.41111 | 12.76928 | .924 | -47.1236 | 26.3013 |
| | | 3.00 | -3.01111 | 12.76928 | .999 | -39.7236 | 33.7013 |
| | | 5.00 | -21.72500 | 16.27770 | .672 | -68.5244 | 25.0744 |
| | 5.00 | 1.00 | -67.10833* | 16.27770 | .002 | -113.9077 | -20.3090 |
| | | 2.00 | 11.31389 | 16.27770 | .956 | -35.4855 | 58.1133 |
| | | 3.00 | 18.71389 | 16.27770 | .779 | -28.0855 | 65.5133 |
| | | 4.00 | 21.72500 | 16.27770 | .672 | -25.0744 | 68.5244 |
| Dry_weight | 1.00 | 2.00 | 9.12036* | 1.55675 | .000 | 4.6446 | 13.5961 |
| | | 3.00 | 9.86513* | 1.55675 | .000 | 5.3894 | 14.3409 |
| | | 4.00 | 10.23010* | 1.55675 | .000 | 5.7543 | 14.7059 |
| | | 5.00 | 7.84510* | 1.98448 | .003 | 2.1396 | 13.5506 |
| | 2.00 | 1.00 | -9.12036* | 1.55675 | .000 | -13.5961 | -4.6446 |
| | | 3.00 | .74478 | 1.55675 | .989 | -3.7310 | 5.2205 |
| | | 4.00 | 1.10974 | 1.55675 | .952 | -3.3660 | 5.5855 |
| | | 5.00 | -1.27526 | 1.98448 | .967 | -6.9808 | 4.4302 |
| | 3.00 | 1.00 | -9.86513* | 1.55675 | .000 | -14.3409 | -5.3894 |
| | | 2.00 | -.74478 | 1.55675 | .989 | -5.2205 | 3.7310 |
| | | 4.00 | .36497 | 1.55675 | .999 | -4.1108 | 4.8407 |
| | | 5.00 | -2.02003 | 1.98448 | .845 | -7.7255 | 3.6855 |
| | 4.00 | 1.00 | -10.23010* | 1.55675 | .000 | -14.7059 | -5.7543 |
| | | 2.00 | -1.10974 | 1.55675 | .952 | -5.5855 | 3.3660 |
| | | 3.00 | -.36497 | 1.55675 | .999 | -4.8407 | 4.1108 |
| | | 5.00 | -2.38500 | 1.98448 | .750 | -8.0905 | 3.3205 |
| | 5.00 | 1.00 | -7.84510* | 1.98448 | .003 | -13.5506 | -2.1396 |
| | | 2.00 | 1.27526 | 1.98448 | .967 | -4.4302 | 6.9808 |
| | | 3.00 | 2.02003 | 1.98448 | .845 | -3.6855 | 7.7255 |
| | | 4.00 | 2.38500 | 1.98448 | .750 | -3.3205 | 8.0905 |

*. The mean difference is significant at the 0.05 level.

One Way Anova for parallels of New Zealand Spinach

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | Minimum | |
|---|---|---|---|---|---|---|---|---|---|
| Start_weight | 1.00 | 9 | 1.0000 | .00000 | .00000 | 1.0000 | 1.0000 | 1.00 | |
| | 2.00 | 9 | 1.2200 | .00000 | .00000 | 1.2200 | 1.2200 | 1.22 | |
| | 3.00 | 9 | 1.1100 | .00000 | .00000 | 1.1100 | 1.1100 | 1.11 | |
| | 4.00 | 9 | 1.1100 | .00000 | .00000 | 1.1100 | 1.1100 | 1.11 | |
| | 5.00 | 4 | 1.1100 | .00000 | .00000 | 1.1100 | 1.1100 | 1.11 | |
| | Total | 40 | 1.1100 | .07473 | .01182 | 1.0861 | 1.1339 | 1.00 | |
| End_weight | 1.00 | 9 | 13.7667 | 15.25287 | 5.08429 | 2.0423 | 25.4911 | 3.10 | |
| | 2.00 | 9 | .4778 | .48677 | .16226 | .1036 | .8519 | .00 | |
| | 3.00 | 9 | .5000 | .49244 | .16415 | .1215 | .8785 | .00 | |
| | 4.00 | 9 | .2333 | .37081 | .12360 | -.0517 | .5184 | .00 | |
| | 5.00 | 4 | 3.5250 | 1.02429 | .51214 | 1.8951 | 5.1549 | 2.40 | |
| | Total | 40 | 3.7225 | 8.87981 | 1.40402 | .8826 | 6.5624 | .00 | |
| Dry_weight | 1.00 | 9 | .9842 | .98690 | .32897 | .2256 | 1.7428 | .33 | |
| | 2.00 | 9 | .0962 | .08455 | .02818 | .0312 | .1612 | .00 | |
| | 3.00 | 9 | .0858 | .07310 | .02437 | .0296 | .1420 | .00 | |
| | 4.00 | 9 | .1545 | .35936 | .11979 | -.1217 | .4307 | .00 | |
| | 5.00 | 4 | .3529 | .07844 | .03922 | .2281 | .4777 | .27 | |
| | Total | 40 | .3324 | .60135 | .09508 | .1401 | .5248 | .00 | |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Start_weight | Between Groups | .218 | 4 | .054 | . | . |
| | Within Groups | .000 | 35 | .000 | | |
| | Total | .218 | 39 | | | |
| End_weight | Between Groups | 1205.907 | 4 | 301.477 | 5.645 | .001 |
| | Within Groups | 1869.283 | 35 | 53.408 | | |
| | Total | 3075.190 | 39 | | | |
| Dry_weight | Between Groups | 5.160 | 4 | 1.290 | 5.048 | .003 |
| | Within Groups | 8.943 | 35 | .256 | | |
| | Total | 14.103 | 39 | | | |

**Post Hoc Tests**

**Multiple Comparisons**

Tukey HSD

| Dependent Variable | (I) Parallel | (J) Parallel | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| End_weight | 1.00 | 2.00 | 13.28889* | 3.44506 | .004 | 3.3841 | 23.1937 |
| | | 3.00 | 13.26667* | 3.44506 | .004 | 3.3619 | 23.1714 |
| | | 4.00 | 13.53333* | 3.44506 | .003 | 3.6286 | 23.4381 |
| | | 5.00 | 10.24167 | 4.39161 | .159 | -2.3845 | 22.8678 |
| | 2.00 | 1.00 | -13.28889* | 3.44506 | .004 | -23.1937 | -3.3841 |
| | | 3.00 | -.02222 | 3.44506 | 1.000 | -9.9270 | 9.8825 |
| | | 4.00 | .24444 | 3.44506 | 1.000 | -9.6603 | 10.1492 |
| | | 5.00 | -3.04722 | 4.39161 | .956 | -15.6734 | 9.5789 |
| | 3.00 | 1.00 | -13.26667* | 3.44506 | .004 | -23.1714 | -3.3619 |
| | | 2.00 | .02222 | 3.44506 | 1.000 | -9.8825 | 9.9270 |
| | | 4.00 | .26667 | 3.44506 | 1.000 | -9.6381 | 10.1714 |
| | | 5.00 | -3.02500 | 4.39161 | .958 | -15.6511 | 9.6011 |
| | 4.00 | 1.00 | -13.53333* | 3.44506 | .003 | -23.4381 | -3.6286 |
| | | 2.00 | -.24444 | 3.44506 | 1.000 | -10.1492 | 9.6603 |
| | | 3.00 | -.26667 | 3.44506 | 1.000 | -10.1714 | 9.6381 |
| | | 5.00 | -3.29167 | 4.39161 | .943 | -15.9178 | 9.3345 |
| | 5.00 | 1.00 | -10.24167 | 4.39161 | .159 | -22.8678 | 2.3845 |
| | | 2.00 | 3.04722 | 4.39161 | .956 | -9.5789 | 15.6734 |
| | | 3.00 | 3.02500 | 4.39161 | .958 | -9.6011 | 15.6511 |
| | | 4.00 | 3.29167 | 4.39161 | .943 | -9.3345 | 15.9178 |
| Dry_weight | 1.00 | 2.00 | .88803* | .23829 | .006 | .2029 | 1.5731 |
| | | 3.00 | .89842* | .23829 | .005 | .2133 | 1.5835 |
| | | 4.00 | .82971* | .23829 | .011 | .1446 | 1.5148 |
| | | 5.00 | .63127 | .30376 | .252 | -.2421 | 1.5046 |
| | 2.00 | 1.00 | -.88803* | .23829 | .006 | -1.5731 | -.2029 |
| | | 3.00 | .01039 | .23829 | 1.000 | -.6747 | .6955 |
| | | 4.00 | -.05832 | .23829 | .999 | -.7434 | .6268 |
| | | 5.00 | -.25676 | .30376 | .914 | -1.1301 | .6166 |
| | 3.00 | 1.00 | -.89842* | .23829 | .005 | -1.5835 | -.2133 |
| | | 2.00 | -.01039 | .23829 | 1.000 | -.6955 | .6747 |
| | | 4.00 | -.06871 | .23829 | .998 | -.7538 | .6164 |
| | | 5.00 | -.26715 | .30376 | .903 | -1.1405 | .6062 |
| | 4.00 | 1.00 | -.82971* | .23829 | .011 | -1.5148 | -.1446 |
| | | 2.00 | .05832 | .23829 | .999 | -.6268 | .7434 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 3.00 | .06871 | .23829 | .998 | -.6164 | .7538 |
| | 5.00 | -.19844 | .30376 | .965 | -1.0718 | .6749 |
| 5.00 | 1.00 | -.63127 | .30376 | .252 | -1.5046 | .2421 |
| | 2.00 | .25676 | .30376 | .914 | -.6166 | 1.1301 |
| | 3.00 | .26715 | .30376 | .903 | -.6062 | 1.1405 |
| | 4.00 | .19844 | .30376 | .965 | -.6749 | 1.0718 |

*. The mean difference is significant at the 0.05 level.

## Appendix 12 – ANOVA Results Height

Tomato plants

**Oneway**

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound |
|---|---|---|---|---|---|---|---|
| Height_aerial_start | 1.00 | 9 | 106.6667 | 8.66025 | 2.88675 | 100.0098 | 113.3235 |
| | 2.00 | 9 | 188.8889 | 44.28443 | 14.76148 | 154.8489 | 222.9289 |
| | 3.00 | 9 | 221.1111 | 31.40241 | 10.46747 | 196.9731 | 245.2491 |
| | 4.00 | 9 | 106.1111 | 9.27961 | 3.09320 | 98.9782 | 113.2440 |
| | 5.00 | 4 | 95.0000 | 10.00000 | 5.00000 | 79.0878 | 110.9122 |
| | Total | 40 | 149.6250 | 57.87240 | 9.15043 | 131.1165 | 168.1335 |
| Height_aerial_mid | 1.00 | 9 | 201.6667 | 26.69270 | 8.89757 | 181.1488 | 222.1845 |
| | 2.00 | 9 | 78.3333 | 16.95582 | 5.65194 | 65.2999 | 91.3667 |
| | 3.00 | 9 | 82.7778 | 13.94433 | 4.64811 | 72.0592 | 93.4963 |
| | 4.00 | 9 | .0000 | .00000 | .00000 | .0000 | .0000 |
| | 5.00 | 4 | 112.5000 | 11.90238 | 5.95119 | 93.5607 | 131.4393 |
| | Total | 40 | 92.8750 | 71.34143 | 11.28007 | 70.0589 | 115.6911 |
| Height_aerial_end | 1.00 | 9 | 334.4444 | 61.25992 | 20.41997 | 287.3559 | 381.5330 |
| | 2.00 | 9 | 132.2222 | 11.75561 | 3.91854 | 123.1861 | 141.2584 |
| | 3.00 | 9 | 106.6667 | 20.00000 | 6.66667 | 91.2933 | 122.0400 |
| | 4.00 | 9 | .0000 | .00000 | .00000 | .0000 | .0000 |
| | 5.00 | 4 | 188.5000 | 32.64455 | 16.32228 | 136.5552 | 240.4448 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total | 40 | 147.8500 | 121.07331 | 19.14337 | 109.1289 | 186.5711 | | |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Height_aerial_start | Between Groups | 105452.708 | 4 | 26363.177 | 36.664 | .000 |
| | Within Groups | 25166.667 | 35 | 719.048 | | |
| | Total | 130619.375 | 39 | | | |
| Height_aerial_mid | Between Groups | 188513.819 | 4 | 47128.455 | 165.271 | .000 |
| | Within Groups | 9980.556 | 35 | 285.159 | | |
| | Total | 198494.375 | 39 | | | |
| Height_aerial_end | Between Groups | 534166.322 | 4 | 133541.581 | 124.557 | .000 |
| | Within Groups | 37524.778 | 35 | 1072.137 | | |
| | Total | 571691.100 | 39 | | | |

**Post Hoc Tests**

**Multiple Comparisons**

Tukey HSD

| Dependent Variable | (I) Parallel | (J) Parallel | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| Height_aerial_start | 1.00 | 2.00 | -82.22222* | 12.64074 | .000 | -118.5651 | -45.8793 |
| | | 3.00 | -114.44444* | 12.64074 | .000 | -150.7873 | -78.1015 |
| | | 4.00 | .55556 | 12.64074 | 1.000 | -35.7873 | 36.8985 |
| | | 5.00 | 11.66667 | 16.11385 | .949 | -34.6616 | 57.9950 |
| | 2.00 | 1.00 | 82.22222* | 12.64074 | .000 | 45.8793 | 118.5651 |
| | | 3.00 | -32.22222 | 12.64074 | .103 | -68.5651 | 4.1207 |
| | | 4.00 | 82.77778* | 12.64074 | .000 | 46.4349 | 119.1207 |
| | | 5.00 | 93.88889* | 16.11385 | .000 | 47.5606 | 140.2172 |
| | 3.00 | 1.00 | 114.44444* | 12.64074 | .000 | 78.1015 | 150.7873 |
| | | 2.00 | 32.22222 | 12.64074 | .103 | -4.1207 | 68.5651 |
| | | 4.00 | 115.00000* | 12.64074 | .000 | 78.6571 | 151.3429 |
| | | 5.00 | 126.11111* | 16.11385 | .000 | 79.7828 | 172.4394 |
| | 4.00 | 1.00 | -.55556 | 12.64074 | 1.000 | -36.8985 | 35.7873 |
| | | 2.00 | -82.77778* | 12.64074 | .000 | -119.1207 | -46.4349 |
| | | 3.00 | -115.00000* | 12.64074 | .000 | -151.3429 | -78.6571 |
| | | 5.00 | 11.11111 | 16.11385 | .957 | -35.2172 | 57.4394 |
| | 5.00 | 1.00 | -11.66667 | 16.11385 | .949 | -57.9950 | 34.6616 |
| | | 2.00 | -93.88889* | 16.11385 | .000 | -140.2172 | -47.5606 |
| | | 3.00 | -126.11111* | 16.11385 | .000 | -172.4394 | -79.7828 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4.00 | -11.11111 | 16.11385 | .957 | -57.4394 | 35.2172 |
| Height_aerial_mid | 1.00 | 2.00 | 123.33333* | 7.96044 | .000 | 100.4466 | 146.2201 |
| | | 3.00 | 118.88889* | 7.96044 | .000 | 96.0021 | 141.7756 |
| | | 4.00 | 201.66667* | 7.96044 | .000 | 178.7799 | 224.5534 |
| | | 5.00 | 89.16667* | 10.14761 | .000 | 59.9917 | 118.3417 |
| | 2.00 | 1.00 | -123.33333* | 7.96044 | .000 | -146.2201 | -100.4466 |
| | | 3.00 | -4.44444 | 7.96044 | .980 | -27.3312 | 18.4423 |
| | | 4.00 | 78.33333* | 7.96044 | .000 | 55.4466 | 101.2201 |
| | | 5.00 | -34.16667* | 10.14761 | .015 | -63.3417 | -4.9917 |
| | 3.00 | 1.00 | -118.88889* | 7.96044 | .000 | -141.7756 | -96.0021 |
| | | 2.00 | 4.44444 | 7.96044 | .980 | -18.4423 | 27.3312 |
| | | 4.00 | 82.77778* | 7.96044 | .000 | 59.8910 | 105.6645 |
| | | 5.00 | -29.72222* | 10.14761 | .044 | -58.8972 | -.5472 |
| | 4.00 | 1.00 | -201.66667* | 7.96044 | .000 | -224.5534 | -178.7799 |
| | | 2.00 | -78.33333* | 7.96044 | .000 | -101.2201 | -55.4466 |
| | | 3.00 | -82.77778* | 7.96044 | .000 | -105.6645 | -59.8910 |
| | | 5.00 | -112.50000* | 10.14761 | .000 | -141.6750 | -83.3250 |
| | 5.00 | 1.00 | -89.16667* | 10.14761 | .000 | -118.3417 | -59.9917 |
| | | 2.00 | 34.16667* | 10.14761 | .015 | 4.9917 | 63.3417 |
| | | 3.00 | 29.72222* | 10.14761 | .044 | .5472 | 58.8972 |
| | | 4.00 | 112.50000* | 10.14761 | .000 | 83.3250 | 141.6750 |
| Height_aerial_end | 1.00 | 2.00 | 202.22222* | 15.43543 | .000 | 157.8444 | 246.6000 |
| | | 3.00 | 227.77778* | 15.43543 | .000 | 183.4000 | 272.1556 |
| | | 4.00 | 334.44444* | 15.43543 | .000 | 290.0666 | 378.8222 |
| | | 5.00 | 145.94444* | 19.67639 | .000 | 89.3736 | 202.5153 |
| | 2.00 | 1.00 | -202.22222* | 15.43543 | .000 | -246.6000 | -157.8444 |
| | | 3.00 | 25.55556 | 15.43543 | .473 | -18.8222 | 69.9334 |
| | | 4.00 | 132.22222* | 15.43543 | .000 | 87.8444 | 176.6000 |
| | | 5.00 | -56.27778 | 19.67639 | .052 | -112.8486 | .2930 |
| | 3.00 | 1.00 | -227.77778* | 15.43543 | .000 | -272.1556 | -183.4000 |
| | | 2.00 | -25.55556 | 15.43543 | .473 | -69.9334 | 18.8222 |
| | | 4.00 | 106.66667* | 15.43543 | .000 | 62.2889 | 151.0445 |
| | | 5.00 | -81.83333* | 19.67639 | .002 | -138.4041 | -25.2625 |
| | 4.00 | 1.00 | -334.44444* | 15.43543 | .000 | -378.8222 | -290.0666 |
| | | 2.00 | -132.22222* | 15.43543 | .000 | -176.6000 | -87.8444 |
| | | 3.00 | -106.66667* | 15.43543 | .000 | -151.0445 | -62.2889 |
| | | 5.00 | -188.50000* | 19.67639 | .000 | -245.0708 | -131.9292 |
| | 5.00 | 1.00 | -145.94444* | 19.67639 | .000 | -202.5153 | -89.3736 |
| | | 2.00 | 56.27778 | 19.67639 | .052 | -.2930 | 112.8486 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 3.00 | 81.83333* | 19.67639 | .002 | 25.2625 | 138.4041 |
| | 4.00 | 188.50000* | 19.67639 | .000 | 131.9292 | 245.0708 |

*. The mean difference is significant at the 0.05 level.

New Zealand Spinach

**Oneway**

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | | |
|---|---|---|---|---|---|---|---|---|---|
| Height_aerial_start | 1.00 | 9 | 44.4444 | 12.85604 | 4.28535 | 34.5624 | 54.3265 | | |
| | 2.00 | 9 | 45.5556 | 10.13794 | 3.37931 | 37.7628 | 53.3483 | | |
| | 3.00 | 9 | 42.7778 | 14.38556 | 4.79519 | 31.7201 | 53.8355 | | |
| | 4.00 | 9 | 48.3333 | 13.22876 | 4.40959 | 38.1648 | 58.5019 | | |
| | 5.00 | 4 | 36.0000 | 8.60233 | 4.30116 | 22.3118 | 49.6882 | | |
| | Total | 40 | 44.3500 | 12.27787 | 1.94130 | 40.4233 | 48.2767 | | |
| Height_aerial_mid | 1.00 | 9 | 28.3333 | 7.07107 | 2.35702 | 22.8980 | 33.7686 | | |
| | 2.00 | 9 | 15.5556 | 11.02396 | 3.67465 | 7.0818 | 24.0293 | | |
| | 3.00 | 9 | 15.0000 | 10.60660 | 3.53553 | 6.8470 | 23.1530 | | |
| | 4.00 | 9 | 12.2222 | 4.40959 | 1.46986 | 8.8327 | 15.6117 | | |
| | 5.00 | 4 | 22.5000 | 5.00000 | 2.50000 | 14.5439 | 30.4561 | | |
| | Total | 40 | 18.2500 | 10.09887 | 1.59677 | 15.0202 | 21.4798 | | |
| Height_aerial_end | 1.00 | 9 | 108.3333 | 45.89390 | 15.29797 | 73.0562 | 143.6105 | | |
| | 2.00 | 9 | 26.1111 | 21.03238 | 7.01079 | 9.9442 | 42.2780 | | |
| | 3.00 | 9 | 18.8889 | 15.16117 | 5.05372 | 7.2350 | 30.5428 | | |
| | 4.00 | 9 | 10.5556 | 13.09686 | 4.36562 | .4884 | 20.6227 | | |
| | 5.00 | 4 | 45.0000 | 8.16497 | 4.08248 | 32.0077 | 57.9923 | | |
| | Total | 40 | 41.3750 | 45.12074 | 7.13422 | 26.9447 | 55.8053 | | |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Height_aerial_start | Between Groups | 457.100 | 4 | 114.275 | .738 | .573 |
| | Within Groups | 5422.000 | 35 | 154.914 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Total | 5879.100 | 39 | | | |
| Height_aerial_mid | Between Groups | 1474.722 | 4 | 368.681 | 5.156 | .002 |
| | Within Groups | 2502.778 | 35 | 71.508 | | |
| | Total | 3977.500 | 39 | | | |
| Height_aerial_end | Between Groups | 55599.375 | 4 | 13899.844 | 20.441 | .000 |
| | Within Groups | 23800.000 | 35 | 680.000 | | |
| | Total | 79399.375 | 39 | | | |

**Post Hoc Tests**

**Multiple Comparisons**

Tukey HSD

| Dependent Variable | (I) Parallel | (J) Parallel | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| Height_aerial_start | 1.00 | 2.00 | -1.11111 | 5.86732 | 1.000 | -17.9800 | 15.7578 |
| | | 3.00 | 1.66667 | 5.86732 | .999 | -15.2022 | 18.5356 |
| | | 4.00 | -3.88889 | 5.86732 | .963 | -20.7578 | 12.9800 |
| | | 5.00 | 8.44444 | 7.47939 | .790 | -13.0593 | 29.9481 |
| | 2.00 | 1.00 | 1.11111 | 5.86732 | 1.000 | -15.7578 | 17.9800 |
| | | 3.00 | 2.77778 | 5.86732 | .989 | -14.0911 | 19.6467 |
| | | 4.00 | -2.77778 | 5.86732 | .989 | -19.6467 | 14.0911 |
| | | 5.00 | 9.55556 | 7.47939 | .706 | -11.9481 | 31.0593 |
| | 3.00 | 1.00 | -1.66667 | 5.86732 | .999 | -18.5356 | 15.2022 |
| | | 2.00 | -2.77778 | 5.86732 | .989 | -19.6467 | 14.0911 |
| | | 4.00 | -5.55556 | 5.86732 | .876 | -22.4244 | 11.3133 |
| | | 5.00 | 6.77778 | 7.47939 | .893 | -14.7259 | 28.2815 |
| | 4.00 | 1.00 | 3.88889 | 5.86732 | .963 | -12.9800 | 20.7578 |
| | | 2.00 | 2.77778 | 5.86732 | .989 | -14.0911 | 19.6467 |
| | | 3.00 | 5.55556 | 5.86732 | .876 | -11.3133 | 22.4244 |
| | | 5.00 | 12.33333 | 7.47939 | .478 | -9.1704 | 33.8370 |
| | 5.00 | 1.00 | -8.44444 | 7.47939 | .790 | -29.9481 | 13.0593 |
| | | 2.00 | -9.55556 | 7.47939 | .706 | -31.0593 | 11.9481 |
| | | 3.00 | -6.77778 | 7.47939 | .893 | -28.2815 | 14.7259 |
| | | 4.00 | -12.33333 | 7.47939 | .478 | -33.8370 | 9.1704 |
| Height_aerial_mid | 1.00 | 2.00 | 12.77778* | 3.98631 | .023 | 1.3169 | 24.2387 |
| | | 3.00 | 13.33333* | 3.98631 | .016 | 1.8725 | 24.7942 |
| | | 4.00 | 16.11111* | 3.98631 | .002 | 4.6502 | 27.5720 |
| | | 5.00 | 5.83333 | 5.08157 | .780 | -8.7765 | 20.4431 |
| | 2.00 | 1.00 | -12.77778* | 3.98631 | .023 | -24.2387 | -1.3169 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3.00 | .55556 | 3.98631 | 1.000 | -10.9053 | 12.0164 |
| | | 4.00 | 3.33333 | 3.98631 | .917 | -8.1275 | 14.7942 |
| | | 5.00 | -6.94444 | 5.08157 | .652 | -21.5543 | 7.6654 |
| | 3.00 | 1.00 | -13.33333* | 3.98631 | .016 | -24.7942 | -1.8725 |
| | | 2.00 | -.55556 | 3.98631 | 1.000 | -12.0164 | 10.9053 |
| | | 4.00 | 2.77778 | 3.98631 | .956 | -8.6831 | 14.2387 |
| | | 5.00 | -7.50000 | 5.08157 | .584 | -22.1098 | 7.1098 |
| | 4.00 | 1.00 | -16.11111* | 3.98631 | .002 | -27.5720 | -4.6502 |
| | | 2.00 | -3.33333 | 3.98631 | .917 | -14.7942 | 8.1275 |
| | | 3.00 | -2.77778 | 3.98631 | .956 | -14.2387 | 8.6831 |
| | | 5.00 | -10.27778 | 5.08157 | .277 | -24.8876 | 4.3320 |
| | 5.00 | 1.00 | -5.83333 | 5.08157 | .780 | -20.4431 | 8.7765 |
| | | 2.00 | 6.94444 | 5.08157 | .652 | -7.6654 | 21.5543 |
| | | 3.00 | 7.50000 | 5.08157 | .584 | -7.1098 | 22.1098 |
| | | 4.00 | 10.27778 | 5.08157 | .277 | -4.3320 | 24.8876 |
| Height_aerial_end | 1.00 | 2.00 | 82.22222* | 12.29273 | .000 | 46.8799 | 117.5646 |
| | | 3.00 | 89.44444* | 12.29273 | .000 | 54.1021 | 124.7868 |
| | | 4.00 | 97.77778* | 12.29273 | .000 | 62.4354 | 133.1201 |
| | | 5.00 | 63.33333* | 15.67021 | .002 | 18.2805 | 108.3861 |
| | 2.00 | 1.00 | -82.22222* | 12.29273 | .000 | -117.5646 | -46.8799 |
| | | 3.00 | 7.22222 | 12.29273 | .976 | -28.1201 | 42.5646 |
| | | 4.00 | 15.55556 | 12.29273 | .714 | -19.7868 | 50.8979 |
| | | 5.00 | -18.88889 | 15.67021 | .748 | -63.9417 | 26.1639 |
| | 3.00 | 1.00 | -89.44444* | 12.29273 | .000 | -124.7868 | -54.1021 |
| | | 2.00 | -7.22222 | 12.29273 | .976 | -42.5646 | 28.1201 |
| | | 4.00 | 8.33333 | 12.29273 | .960 | -27.0090 | 43.6757 |
| | | 5.00 | -26.11111 | 15.67021 | .467 | -71.1639 | 18.9417 |
| | 4.00 | 1.00 | -97.77778* | 12.29273 | .000 | -133.1201 | -62.4354 |
| | | 2.00 | -15.55556 | 12.29273 | .714 | -50.8979 | 19.7868 |
| | | 3.00 | -8.33333 | 12.29273 | .960 | -43.6757 | 27.0090 |
| | | 5.00 | -34.44444 | 15.67021 | .204 | -79.4973 | 10.6084 |
| | 5.00 | 1.00 | -63.33333* | 15.67021 | .002 | -108.3861 | -18.2805 |
| | | 2.00 | 18.88889 | 15.67021 | .748 | -26.1639 | 63.9417 |
| | | 3.00 | 26.11111 | 15.67021 | .467 | -18.9417 | 71.1639 |
| | | 4.00 | 34.44444 | 15.67021 | .204 | -10.6084 | 79.4973 |

*. The mean difference is significant at the 0.05 level.

## Appendix 13 - Quality Classes for Fertilizers

| Quality classes of fertilizers | | | | | | |
|---|---|---|---|---|---|---|
| Heavy metals | Dried fish waste used in experiment* | | Quality classes (Gjødselvareforskrift**) | | | |
| | | | O | I | II | III |
| Cd | 0,6 | ±20% | 0,4 | 0,8 | 2 | 5 |
| Pb | 0,5 | ±20% | 40 | 60 | 80 | 200 |
| Hg | 0,068 | ±20% | 0,2 | 0,6 | 3 | 5 |
| Ni | 1 | ±20% | 20 | 30 | 50 | 80 |
| Zn | 410 | ±20% | 150 | 400 | 800 | 1500 |
| Cu | 14 | ±20% | 50 | 150 | 650 | 1000 |
| Cr | 2,9 | ±20% | 50 | 60 | 100 | 150 |
| As | | | 5 | 8 | 16 | 32 |
| All numbers in mg/kg dry matter | | | | | | |

**Fish waste analyzed by Eurofins*

***Gjødselvareforskriften FOR-2003-07-04-951*

# Appendix 14 – Raw data (Excel)

Date: 27.04.2020

| Start weight | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total | Average | Standard deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 'Balkonzauber' Tomato Plant | 1 | Height total [mm] | 190 | 200 | 220 | 200 | 280 | 240 | 310 | 210 | 200 | 2050 | 227,8 | 41,5 |
| | | Height aerial[mm] | 120 | 105 | 105 | 115 | 100 | 90 | 110 | 105 | 110 | 960 | 106,7 | 8,7 |
| | | Height roots[mm] | 70 | 95 | 115 | 85 | 180 | 180 | 200 | 105 | 90 | 1120 | 124,4 | 48,6 |
| | | Weight [g] | 2 | 2 | 2 | 3 | 2 | 2 | 3 | 3 | 0,5 | 19,5 | 2,2 | 0,8 |
| | 2 | Height total [mm] | 100 | 170 | 190 | 220 | 200 | 160 | 210 | 260 | 190 | 1700 | 188,9 | 44,3 |
| | | Height aerial[mm] | 70 | 100 | 110 | 100 | 95 | 90 | 105 | 110 | 90 | 870 | 96,7 | 12,5 |
| | | Height roots[mm] | 30 | 70 | 80 | 120 | 105 | 70 | 105 | 150 | 100 | 830 | 92,2 | 34,5 |
| | | Weight [g] | 0,5 | 3 | 2 | 4 | 2 | 3 | 3 | 2 | 2 | 21,5 | 2,4 | 1,0 |
| | 3 | Height total [mm] | 190 | 180 | 240 | 280 | 210 | 250 | 220 | 200 | 220 | 1990 | 221,1 | 31,4 |
| | | Height aerial[mm] | 110 | 100 | 120 | 120 | 105 | 100 | 130 | 125 | 120 | 1030 | 114,4 | 11,0 |
| | | Height roots[mm] | 80 | 80 | 120 | 169 | 105 | 150 | 90 | 75 | 100 | 969 | 107,7 | 32,9 |
| | | Weight [g] | 0,5 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 3 | 25,5 | 2,8 | 1,1 |
| | 4 | Height total [mm] | 230 | 230 | 300 | 280 | 280 | 205 | 260 | 210 | 200 | 2195 | 243,9 | 37,1 |
| | | Height aerial[mm] | 110 | 95 | 120 | 120 | 110 | 100 | 100 | 100 | 100 | 955 | 106,1 | 9,3 |
| | | Height roots[mm] | 120 | 135 | 180 | 160 | 170 | 105 | 160 | 110 | 100 | 1240 | 137,8 | 30,4 |
| | | Weight [g] | 3 | 2 | 2 | 2 | 0,5 | 3 | 2 | 2 | 2 | 18,5 | 2,1 | 0,7 |
| | 5 | Height total [mm] | | | | | | | | | | | | |
| | | Height aerial[mm] | 90 | 90 | 90 | 110 | | | | | | 380 | 95,0 | 10,0 |
| | | Height roots[mm] | | | | | | | | | | | | |
| | | Weight [g] | | | | | | | | | | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Zealand Spinach | 1 | Height total [mm] | 105 | 120 | 110 | 105 | 110 | 135 | 120 | 110 | 110 | | 113,9 | 9,6 |
| | | Height aerial[mm] | 60 | 40 | 25 | 45 | 30 | 65 | 50 | 40 | 45 | | 44,4 | 12,9 |
| | | Height roots[mm] | 45 | 80 | 85 | 60 | 80 | 70 | 70 | 70 | 65 | | 69,4 | 12,1 |
| | | Weight [g] | | | | | | | | | | 9 g | | |
| | 2 | Height total [mm] | 100 | 110 | 130 | 135 | 110 | 110 | 150 | 90 | 115 | | 116,7 | 18,5 |
| | | Height aerial[mm] | 45 | 30 | 50 | 55 | 55 | 40 | 50 | 30 | 55 | | 45,6 | 10,1 |
| | | Height roots[mm] | 55 | 80 | 80 | 80 | 55 | 70 | 100 | 60 | 60 | | 71,1 | 15,2 |
| | | Weight [g] | | | | | | | | | | 11g | | |
| | 3 | Height total [mm] | 120 | 130 | 110 | 110 | 130 | 150 | 150 | 110 | 110 | | 124,4 | 16,7 |
| | | Height aerial[mm] | 65 | 65 | 30 | 35 | 40 | 40 | 25 | 50 | 35 | | 42,8 | 14,4 |
| | | Height roots[mm] | 55 | 65 | 80 | 75 | 90 | 110 | 125 | 60 | 75 | | 81,7 | 23,2 |
| | | Weight [g] | | | | | | | | | | 10g | | |
| | 4 | Height total [mm] | 140 | 105 | 110 | 120 | 150 | 130 | 140 | 135 | 125 | | 128,3 | 14,8 |
| | | Height aerial[mm] | 70 | 30 | 35 | 40 | 65 | 55 | 45 | 45 | 50 | | 48,3 | 13,2 |
| | | Height roots[mm] | 70 | 75 | 75 | 80 | 85 | 75 | 95 | 90 | 75 | | 80,0 | 8,3 |
| | | Weight [g] | | | | | | | | | | 10g | | |
| | 5 | Height total [mm] | | | | | | | | | | | | |
| | | Height aerial[mm] | 40 | 45 | 25 | 34 | | | | | | 144 | 36,0 | 8,6 |
| | | Height roots[mm] | | | | | | | | | | | | |
| | | Weight [g] | | | | | | | | | | | | |

Date: 13.05.2020 Hight half way in the experiment. Only plant height above leca. Roots under pot with slime from waste product.

| **Wet weight, mid experiment.** | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total | Average | Standard derivation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ´Balkonzauber' Tomato Plant | 1 | Total height [mm] | 355 | 365 | 330 | 515 | 405 | 390 | 330 | 360 | 225 | 3275 | 363,9 | 76,6 |
| | | Height upper part [mm] | 175 | 215 | 200 | 235 | 215 | 230 | 180 | 210 | 155 | 1815 | 201,7 | 26,7 |
| | | Roots [mm] | 180 | 150 | 130 | 280 | 190 | 160 | 150 | 150 | 70 | 1460 | 162,2 | 55,9 |
| | 2 | Total height [mm] | 110 | 180 | 120 | 180 | 180 | 110 | 190 | 200 | 155 | 1425 | 158,3 | 35,9 |
| | | Height upper part [mm] | 80 | 110 | 50 | 80 | 80 | 60 | 90 | 80 | 75 | 705 | 78,3 | 17,0 |
| | | Roots [mm] | 30 | 70 | 70 | 100 | 100 | 50 | 100 | 120 | 80 | 720 | 80,0 | 28,3 |
| | 3 | Total height [mm] | 170 | 140 | 200 | 190 | 180 | 170 | 190 | 135 | 140 | 1515 | 168,3 | 24,5 |
| | | Height upper part [mm] | 90 | 70 | 100 | 70 | 80 | 60 | 100 | 85 | 90 | 745 | 82,8 | 13,9 |
| | | Roots [mm] | 80 | 70 | 100 | 120 | 100 | 110 | 90 | 50 | 50 | 770 | 85,6 | 25,1 |
| | 4 | Total height [mm] | x | x | x | x | x | x | x | x | x | | | |
| | | Height upper part [mm] | | | | | | | | | | | | |
| | | Roots [mm] | | | | | | | | | | | | |
| | 5 | Total height [mm] | | | | | | | | | | | | |
| | | Height upper part [mm] | 105 | 100 | 120 | 125 | | | | | | 450 | 112,5 | 11,9 |
| | | Roots [mm] | | | | | | | | | | | | |
| New Zealand Spinach | 1 | Total height [mm] | 95 | 120 | 110 | 95 | 120 | 235 | 140 | 120 | 100 | 1135 | 126,1 | 43,4 |
| | | Height upper part [mm] | 25 | 25 | 20 | 25 | 25 | 45 | 30 | 30 | 30 | 255 | 28,3 | 7,1 |
| | | Roots [mm] | 70 | 95 | 90 | 70 | 95 | 190 | 110 | 90 | 70 | 880 | 97,8 | 37,3 |
| | | Number of leaves >10mm | 6 | 6 | 6 | 6 | 7 | 11 | 7 | 7 | 7 | | 7,0 | 1,6 |
| | 2 | Total height [mm] | 55 | 75 | 90 | 80 | x | 90 | x | 80 | 80 | 550 | 78,6 | 11,8 |
| | | Height upper part [mm] | 15 | 15 | 20 | 10 | | 30 | | 20 | 30 | 140 | 20,0 | 7,6 |
| | | Roots [mm] | 40 | 60 | 70 | 70 | | 60 | | 60 | 50 | 410 | 58,6 | 10,7 |
| | | Number of leaves >10mm | 4 | 3 | 5 | 0 | | 4 | | 4 | 6 | | 3,7 | 1,9 |
| | 3 | Total height [mm] | 80 | 80 | 55 | 80 | 120 | 80 | x | x | 90 | 585 | 83,6 | 19,3 |
| | | Height upper part [mm] | 20 | 20 | 5 | 20 | 30 | 20 | | | 20 | 135 | 19,3 | 7,3 |
| | | Roots [mm] | 60 | 60 | 50 | 60 | 90 | 60 | | | 70 | 450 | 64,3 | 12,7 |
| | | Number of leaves >10mm | 4 | 4 | 2 | 2 | 2 | 5 | | | 3 | | 3,1 | 1,2 |
| | 4 | Total height [mm] | 90 | 70 | 90 | 80 | 90 | 90 | 70 | 80 | 60 | 720 | 80,0 | 11,2 |
| | | Height upper part [mm] | 20 | 10 | 20 | 10 | 10 | 10 | 10 | 10 | 10 | 110 | 12,2 | 4,4 |
| | | Roots [mm] | 70 | 60 | 70 | 70 | 80 | 80 | 60 | 70 | 50 | 610 | 67,8 | 9,7 |
| | | Number of leaves >10mm | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2,4 | 0,9 |
| | 5 | Total height [mm] | | | | | | | | | | | | |
| | | Height upper part [mm] | 20 | 20 | 30 | 20 | | | | | | 90 | 22,5 | 5,0 |
| | | Roots [mm] | | | | | | | | | | | | |
| | | Number of leaves >10mm | 4 | 6 | 6 | 6 | | | | | | | 5,5 | 1,0 |

Date: 26.05.2020 End measurements

| Wet weight, end of experiment. | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total | Average | Standard deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ´Balkonzauber' Tomato Plant | 1 | Height total [mm] | 720 | 655 | 530 | 585 | 540 | 505 | 360 | 540 | 465 | 4900 | 544,4 | 104,2 |
| | | Height aerial[mm] | 370 | 375 | 360 | 425 | 320 | 285 | 210 | 340 | 325 | 3010 | 334,4 | 61,3 |
| | | Height roots[mm] | 350 | 280 | 170 | 160 | 220 | 220 | 150 | 200 | 140 | 1890 | 210,0 | 68,4 |
| | | Weight total[g] | 174,4 | 159,6 | 45,2 | 135,3 | 70 | 35,6 | 13,8 | 87,7 | 77,9 | 799,5 | 88,8 | 56,3 |
| | | Weight aerial [g] | 104,64 | 101,99 | 28,3 | 81,18 | 46,4 | 18,8 | 8,4 | 51,9 | 41,2 | 482,81 | 53,6 | 35,0 |
| | | Weight roots[g] | 69,76 | 57,61 | 16,9 | 54,12 | 23,6 | 16,8 | 5,4 | 35,8 | 36,7 | 316,69 | 35,2 | 21,7 |
| | 2 | Height total [mm] | 190 | 245 | 210 | 200 | 220 | 215 | 230 | 240 | 215 | 1965 | 218,3 | 17,9 |
| | | Height aerial[mm] | 110 | 150 | 140 | 125 | 140 | 140 | 130 | 130 | 125 | 1190 | 132,2 | 11,8 |
| | | Height roots[mm] | 80 | 95 | 70 | 75 | 80 | 75 | 100 | 110 | 90 | 775 | 86,1 | 13,4 |
| | | Weight total[g] | 8,4 | 9,6 | 11,2 | 10,3 | 8 | 11,6 | 12 | 10 | 12,6 | 93,7 | 10,4 | 1,6 |
| | | Weight aerial [g] | 4,4 | 5,6 | 5,2 | 5,2 | 3,9 | 5,2 | 5 | 4,4 | 6,4 | 45,3 | 5,0 | 0,7 |
| | | Weight roots[g] | 4 | 4 | 6 | 5,1 | 4,1 | 6,4 | 7 | 5,6 | 6,2 | 48,4 | 5,4 | 1,1 |
| | 3 | Height total [mm] | 185 | 170 | 220 | 240 | 250 | 180 | 190 | 220 | 195 | 1850 | 205,6 | 28,0 |
| | | Height aerial[mm] | 95 | 85 | 110 | 150 | 100 | 95 | 90 | 120 | 115 | 960 | 106,7 | 20,0 |
| | | Height roots[mm] | 90 | 85 | 110 | 90 | 150 | 85 | 100 | 100 | 80 | 890 | 98,9 | 21,3 |
| | | Weight total[g] | 1,5 | 2,2 | 2,5 | 3,9 | 3,3 | 3,2 | 2,9 | 4,7 | 2,9 | 27,1 | 3,0 | 0,9 |
| | | Weight aerial [g] | 1,1 | 1,8 | 1,9 | 2,8 | 2,5 | 2,4 | 2 | 3,2 | 2,1 | 19,8 | 2,2 | 0,6 |
| | | Weight roots[g] | 0,4 | 0,4 | 0,6 | 1,1 | 0,7 | 0,8 | 0,9 | 1,5 | 0,8 | 7,2 | 0,8 | 0,3 |
| | 4 | Height total [mm] | x | x | x | x | x | x | x | x | x | x | x | x |
| | | Height aerial[mm] | | | | | | | | | | | | |
| | | Height roots[mm] | | | | | | | | | | | | |
| | | Weight total[g] | | | | | | | | | | | | |
| | | Weight aerial [g] | | | | | | | | | | | | |
| | | Weight roots[g] | | | | | | | | | | | | |
| | 5 | Height total [mm] | 370 | 285 | 405 | 424 | | | | | | 1484 | 371,0 | 61,5 |
| | | Height aerial[mm] | 190 | 145 | 195 | 224 | | | | | | 754 | 188,5 | 32,6 |
| | | Height roots[mm] | 180 | 140 | 210 | 200 | | | | | | 730 | 182,5 | 31,0 |
| | | Weight total[g] | 16,2 | 9,9 | 31,2 | 29,6 | | | | | | 86,9 | 21,7 | 10,4 |
| | | Weight aerial [g] | 10,3 | 6,3 | 19 | 18,9 | | | | | | 54,5 | 13,6 | 6,4 |
| | | Weight roots[g] | 5,9 | 3,6 | 12,2 | 10,7 | | | | | | 32,4 | 8,1 | 4,0 |

Date: 26.05.2020 End measurements

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Zealand Spinach | 1 | Height total [mm] | 260 | 400 | 290 | 295 | 330 | 560 | 420 | 195 | 160 | 2910 | 323,3 | 122,7 |
| | | Height aerial[mm] | 80 | 110 | 70 | 100 | 145 | 200 | 140 | 65 | 65 | 975 | 108,3 | 45,9 |
| | | Height roots[mm] | 180 | 290 | 220 | 195 | 185 | 360 | 280 | 130 | 95 | 1935 | 215,0 | 83,0 |
| | | Weight total[g] | 10,1 | 9,6 | 3,1 | 5,8 | 12 | 50,7 | 24 | 3,3 | 5,3 | 123,9 | 13,8 | 15,3 |
| | | Weight aerial [g] | 8,5 | 8 | 2,7 | 4,9 | 10,2 | 7,5 | 19,8 | 2,7 | 3,9 | 68,2 | 7,6 | 5,3 |
| | | Weight roots[g] | 1,6 | 1,6 | 0,4 | 0,9 | 1,8 | 43,2 | 4,2 | 0,6 | 1,4 | 55,7 | 6,2 | 13,9 |
| | 2 | Height total [mm] | 110 | 115 | x | 145 | x | 120 | x | 100 | 125 | 715 | 119,2 | 15,3 |
| | | Height aerial[mm] | 35 | 45 | | 55 | | 40 | | 30 | 30 | 235 | 39,2 | 9,7 |
| | | Height roots[mm] | 75 | 70 | | 90 | | 80 | | 70 | 95 | 480 | 80,0 | 10,5 |
| | | Weight total[g] | 0,2 | 0,4 | | 1,1 | | 0,7 | | 0,6 | 1,3 | 4,3 | 0,7 | 0,4 |
| | | Weight aerial [g] | 0,2 | 0,4 | | 0,9 | | 0,7 | | 0,6 | 1 | 3,8 | 0,6 | 0,3 |
| | | Weight roots[g] | 0 | 0 | | 0,2 | | 0 | | 0 | 0,3 | 0,5 | 0,1 | 0,1 |
| | 3 | Height total [mm] | 145 | 140 | x | 100 | 120 | 130 | x | x | 110 | 745 | 124,2 | 17,4 |
| | | Height aerial[mm] | 35 | 30 | | 20 | 30 | 35 | | | 20 | 170 | 28,3 | 6,8 |
| | | Height roots[mm] | 110 | 110 | | 80 | 90 | 95 | | | 90 | 575 | 95,8 | 12,0 |
| | | Weight total[g] | 1,5 | 0,7 | | 0,6 | 0,6 | 0,8 | | | 0,3 | 4,5 | 0,8 | 0,4 |
| | | Weight aerial [g] | 1,2 | 0,7 | | 0,6 | 0,6 | 0,8 | | | 0,3 | 4,2 | 0,7 | 0,3 |
| | | Weight roots[g] | 0,3 | 0 | | 0 | 0 | 0 | | | 0 | 0,3 | 0,1 | 0,1 |
| | 4 | Height total [mm] | 135 | 85 | 115 | x | x | 125 | x | x | x | 460 | 115,0 | 21,6 |
| | | Height aerial[mm] | 25 | 15 | 25 | | | 30 | | | | 95 | 23,8 | 6,3 |
| | | Height roots[mm] | 110 | 70 | 90 | | | 95 | | | | 365 | 91,3 | 16,5 |
| | | Weight total[g] | 1,1 | 0,2 | 0,3 | | | 0,5 | | | | 2,1 | 0,5 | 0,4 |
| | | Weight aerial [g] | 1,1 | 0,1 | 0,3 | | | 0,5 | | | | 2 | 0,5 | 0,4 |
| | | Weight roots[g] | 0 | 0,1 | 0 | | | 0 | | | | 0,1 | 0,0 | 0,1 |
| | 5 | Height total [mm] | 100 | 100 | 115 | 85 | | | | | | 400 | 100,0 | 12,2 |
| | | Height aerial[mm] | 45 | 55 | 45 | 35 | | | | | | 180 | 45,0 | 8,2 |
| | | Height roots[mm] | 55 | 45 | 70 | 50 | | | | | | 220 | 55,0 | 10,8 |
| | | Weight total[g] | 3,1 | 3,8 | 4,8 | 2,4 | | | | | | 14,1 | 3,5 | 1,0 |
| | | Weight aerial [g] | 2,5 | 2,9 | 3,5 | 1,8 | | | | | | 10,7 | 2,7 | 0,7 |
| | | Weight roots[g] | 0,6 | 0,9 | 1,3 | 0,6 | | | | | | 3,4 | 0,9 | 0,3 |

Date: 26.05.2020

| Dry weight | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total | Average | Standard deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ´Balkonzauber' Tomato Plants | 1 | Aerial weight [g] | 11,4910 | 11,3370 | 2,6370 | 9,3767 | 4,3890 | 2,0799 | 0,9230 | 5,9763 | 5,0323 | 53,2422 | 5,9 | 4,0 |
| | | Root weight [g] | 8,5630 | 8,3790 | 2,0720 | 6,7240 | 3,1020 | 1,7701 | 0,6360 | 4,1705 | 3,4120 | 38,8286 | 4,3 | 2,9 |
| | | Total dry weight [g] | 20,0540 | 19,7160 | 4,7090 | 16,1007 | 7,4910 | 3,8500 | 1,5590 | 10,1468 | 8,4443 | 92,0708 | 10,2 | 6,9 |
| | 2 | Aerial weight [g] | 0,6533 | 0,8054 | 0,7868 | 0,7172 | 0,5833 | 0,7459 | 0,8486 | 0,6817 | 0,6998 | 6,5220 | 0,7 | 0,1 |
| | | Root weight [g] | 0,3041 | 0,3956 | 0,3230 | 0,3324 | 0,2417 | 0,3858 | 0,4590 | 0,4289 | 0,5952 | 3,4657 | 0,4 | 0,1 |
| | | Total dry weight [g] | 0,9574 | 1,2010 | 1,1098 | 1,0496 | 0,8250 | 1,1317 | 1,3076 | 1,1106 | 1,2950 | 9,9877 | 1,1 | 0,2 |
| | 3 | Aerial weight [g] | 0,1343 | 0,0718 | 0,0877 | 0,3295 | 0,1029 | 0,2906 | 0,2784 | 0,4017 | 0,2227 | 1,9196 | 0,2 | 0,1 |
| | | Root weight [g] | 0,0609 | 0,1962 | 0,2629 | 0,1031 | 0,3019 | 0,0962 | 0,1066 | 0,1486 | 0,0887 | 1,3651 | 0,2 | 0,1 |
| | | Total dry weight [g] | 0,1952 | 0,2680 | 0,3506 | 0,4326 | 0,4048 | 0,3868 | 0,3850 | 0,5503 | 0,3114 | 3,2847 | 0,4 | 0,1 |
| | 4 | Aerial weight [g] | x | x | x | x | x | x | x | x | x | | | |
| | | Root weight [g] | | | | | | | | | | | | |
| | | Total dry weight [g] | | | | | | | | | | | | |
| | 5 | Aerial weight [g] | 0,6231 | 2,0157 | 2,4940 | 1,6370 | | | | | | 6,7698 | 1,7 | 0,8 |
| | | Root weight [g] | 0,4154 | 1,3587 | 0,5948 | 0,4042 | | | | | | 2,7731 | 0,7 | 0,5 |
| | | Total dry weight [g] | 1,0385 | 3,3744 | 3,0888 | 2,0412 | | | | | | 9,5429 | 2,4 | 1,1 |
| | | | | | | | | | | | | | | |
| New Zealand Spinach | 1 | Aerial weight [g] | 0,5577 | 0,5644 | 0,1858 | 0,3350 | 0,6246 | 2,7594 | 1,3351 | 0,2671 | 0,5043 | 7,1334 | 0,8 | 0,8 |
| | | Root weight [g] | 0,1363 | 0,0510 | 0,1412 | 0,0963 | 0,1342 | 0,6278 | 0,3461 | 0,1212 | 0,0703 | 1,7244 | 0,2 | 0,2 |
| | | Total dry weight [g] | 0,6940 | 0,6154 | 0,3270 | 0,4313 | 0,7588 | 3,3872 | 1,6812 | 0,3883 | 0,5746 | 8,8578 | 1,0 | 1,0 |
| | 2 | Aerial weight [g] | 0,0632 | 0,0812 | 0,0000 | 0,1620 | 0,0000 | 0,1189 | 0,0000 | 0,1105 | 0,1843 | 0,7201 | 0,1 | 0,1 |
| | | Root weight [g] | 0,0175 | 0,0145 | 0,0000 | 0,0313 | 0,0000 | 0,0216 | 0,0000 | 0,0196 | 0,0409 | 0,1454 | 0,0 | 0,0 |
| | | Total dry weight [g] | 0,0807 | 0,0957 | 0,0000 | 0,1933 | 0,0000 | 0,1405 | 0,0000 | 0,1301 | 0,2252 | 0,8655 | 0,1 | 0,1 |
| | 3 | Aerial weight [g] | 0,1647 | 0,1030 | 0,0000 | 0,0776 | 0,0778 | 0,1338 | 0,0000 | 0,0000 | 0,0863 | 0,6432 | 0,1 | 0,1 |
| | | Root weight [g] | 0,0382 | 0,0230 | 0,0000 | 0,0143 | 0,0130 | 0,0222 | 0,0000 | 0,0000 | 0,0181 | 0,1288 | 0,0 | 0,0 |
| | | Total dry weight [g] | 0,2029 | 0,1260 | 0,0000 | 0,0919 | 0,0908 | 0,1560 | 0,0000 | 0,0000 | 0,1044 | 0,7720 | 0,1 | 0,1 |
| | 4 | Aerial weight [g] | 0,1155 | 0,0446 | 0,0786 | 0,0000 | 0,0000 | 0,0889 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0 | 0,0 |
| | | Root weight [g] | 0,0271 | 0,0092 | 0,0125 | 0,0000 | 0,0000 | 0,0140 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0 | 0,0 |
| | | Total dry weight [g] | 0,1426 | 0,0538 | 0,0911 | 0,0000 | 0,0000 | 0,1029 | 0,0000 | 0,0000 | 0,0000 | 0,0000 | 0,0 | 0,1 |
| | 5 | Aerial weight [g] | 0,3285 | 0,1839 | 0,2805 | 0,3560 | | | | | | 1,1489 | 0,3 | 0,1 |
| | | Root weight [g] | 0,0483 | 0,0820 | 0,0414 | 0,0932 | | | | | | 0,2649 | 0,1 | 0,0 |
| | | Total dry weight [g] | 0,3768 | 0,2659 | 0,3219 | 0,4492 | | | | | | 1,4138 | 0,4 | 0,1 |

| Weight measurments | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total | Average | Standard derivation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ´Balkonzauber' Tomato Plant | 1 | Wet weight, start [g] | 2,00 | 2,00 | 2,00 | 3,00 | 2,00 | 2,00 | 3,00 | 3,00 | 0,50 | 19,50 | 2,17 | 0,79 |
| | | Wet weight, end [g] | 174,40 | 159,60 | 45,20 | 135,30 | 70,00 | 35,60 | 13,80 | 87,70 | 77,90 | 799,50 | 88,83 | 56,27 |
| | | Dry weight, end [g] | 20,05 | 19,72 | 4,71 | 16,10 | 7,49 | 3,85 | 1,56 | 10,15 | 8,44 | 92,07 | 10,23 | 6,87 |
| | | Daily growth rate total | 6,16 | 5,63 | 1,54 | 4,73 | 2,43 | 1,20 | 0,39 | 3,03 | 2,76 | 27,86 | 3,10 | 2,01 |
| | | Change in weight [g] | 154,35 | 139,88 | 40,49 | 119,20 | 62,51 | 31,75 | 12,24 | 77,55 | 69,46 | 707,43 | 78,60 | 49,42 |
| | | Change in % | 88,50 | 87,65 | 89,58 | 88,10 | 89,30 | 89,19 | 88,70 | 88,43 | 89,16 | 798,61 | 88,73 | 0,63 |
| | 2 | Wet weight, start [g] | 0,50 | 3,00 | 2,00 | 4,00 | 2,00 | 3,00 | 3,00 | 2,00 | 2,00 | 21,50 | 2,39 | 0,99 |
| | | Wet weight, end [g] | 8,40 | 9,60 | 11,20 | 10,30 | 8,00 | 11,60 | 12,00 | 10,00 | 12,60 | 93,70 | 10,41 | 1,58 |
| | | Dry weight, end [g] | 0,96 | 1,20 | 1,11 | 1,05 | 0,83 | 1,13 | 1,31 | 1,11 | 1,30 | 9,99 | 1,11 | 0,15 |
| | | Daily growth rate total | 0,28 | 0,24 | 0,33 | 0,23 | 0,21 | 0,31 | 0,32 | 0,29 | 0,38 | 2,58 | 0,29 | 0,05 |
| | | Change in weight [g] | 7,44 | 8,40 | 10,09 | 9,25 | 7,18 | 10,47 | 10,69 | 8,89 | 11,31 | 83,71 | 9,30 | 1,45 |
| | | Change in % | 88,60 | 87,49 | 90,09 | 89,81 | 89,69 | 90,24 | 89,10 | 88,89 | 89,72 | 803,64 | 89,29 | 0,87 |
| | 3 | Wet weight, start [g] | 0,50 | 2,00 | 3,00 | 3,00 | 3,00 | 3,00 | 4,00 | 4,00 | 3,00 | 25,50 | 2,83 | 1,06 |
| | | Wet weight, end [g] | 1,50 | 2,20 | 2,50 | 3,90 | 3,30 | 3,20 | 2,90 | 4,70 | 2,90 | 27,10 | 3,01 | 0,93 |
| | | Dry weight, end [g] | 0,20 | 0,27 | 0,35 | 0,43 | 0,40 | 0,39 | 0,39 | 0,55 | 0,31 | 3,28 | 0,36 | 0,10 |
| | | Daily growth rate total | 0,04 | 0,01 | -0,02 | 0,03 | 0,01 | 0,01 | -0,04 | 0,03 | 0,00 | 0,06 | 0,01 | 0,02 |
| | | Change in weight [g] | 1,30 | 1,93 | 2,15 | 3,47 | 2,90 | 2,81 | 2,52 | 4,15 | 2,59 | 23,82 | 2,65 | 0,84 |
| | | Change in % | 86,99 | 87,82 | 85,98 | 88,91 | 87,73 | 87,91 | 86,72 | 88,29 | 89,26 | 789,61 | 87,73 | 1,04 |
| | 4 | Wet weight, start [g] | 3,00 | 2,00 | 2,00 | 2,00 | 0,50 | 3,00 | 2,00 | 2,00 | 2,00 | 18,50 | 2,1 | 0,73 |
| | | Wet weight, end [g] | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,0 | 0,00 |
| | | Dry weight, end [g] | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,0 | 0,00 |
| | | Daily growth rate total | -0,11 | -0,07 | -0,07 | -0,07 | -0,02 | -0,11 | -0,07 | -0,07 | -0,07 | -0,66 | -0,1 | 0,03 |
| | | Change in weight [g] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,00 | 0,0 | |
| | | Change in % | | | | | | | | | | | | |
| | 5 | Wet weight, start [g] | 2,40 | 2,40 | 2,40 | 2,40 | | | | | | 9,60 | 2,40 | 0,00 |
| | | Wet weight, end [g] | 9,90 | 29,60 | 31,20 | 16,20 | | | | | | 86,90 | 21,73 | 10,36 |
| | | Dry weight, end [g] | 1,04 | 3,37 | 3,09 | 2,04 | | | | | | 9,54 | 2,39 | 1,07 |
| | | Daily growth rate total | 0,27 | 0,97 | 1,03 | 0,49 | | | | | | 2,76 | 0,69 | 0,37 |
| | | Change in weight [g] | 8,86 | 26,23 | 28,11 | 14,16 | | | | | | 77,36 | 19,34 | 9,33 |
| | | Change in % | 89,51 | 88,60 | 90,10 | 87,40 | | | | | | 355,61 | 88,90 | 1,18 |
| New Zealand Spinach | 1 | Wet weight, start [g] | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 9 | 1 | 0,00 |
| | | Wet weight, end [g] | 10,1 | 9,6 | 3,1 | 5,8 | 12 | 50,7 | 24 | 3,3 | 5,3 | 123,90 | 13,77 | 15,25 |
| | | Dry weight, end [g] | 0,6940 | 0,6154 | 0,3270 | 0,4313 | 0,7588 | 3,3872 | 1,6812 | 0,3883 | 0,5746 | 8,86 | 0,98 | 0,99 |
| | | Daily growth rate total | 0,3 | 0,3 | 0,1 | 0,2 | 0,4 | 1,8 | 0,8 | 0,1 | 0,2 | 4,10 | 0,46 | 0,54 |
| | | Change in weight [g] | 9,41 | 8,98 | 2,77 | 5,37 | 11,24 | 47,31 | 22,32 | 2,91 | 4,73 | 115,04 | 12,78 | 14,27 |
| | | Change in % | 93,13 | 93,59 | 89,45 | 92,56 | 93,68 | 93,32 | 93,00 | 88,23 | 89,16 | 826,12 | 1276,67 | 2,18 |
| | 2 | Wet weight, start [g] | 1,22 | 1,22 | 1,22 | 1,22 | 1,22 | 1,22 | 1,22 | 1,22 | 1,22 | 11,00 | 1,22 | 0,00 |
| | | Wet weight, end [g] | 0,2 | 0,4 | 0 | 1,1 | 0 | 0,7 | 0 | 0,6 | 1,3 | 4,30 | 0,48 | 0,49 |
| | | Dry weight, end [g] | 0,0807 | 0,0957 | 0 | 0,1933 | 0 | 0,1405 | 0 | 0,1301 | 0,2252 | 0,87 | 0,10 | 0,08 |
| | | Daily growth rate total | -0,04 | -0,03 | -0,04 | 0,00 | -0,04 | -0,02 | -0,04 | -0,02 | 0,00 | -0,24 | -0,03 | 0,02 |
| | | Change in weight [g] | 0,1193 | 0,3043 | 0 | 0,9067 | | 0,5595 | | 0,4699 | 1,0748 | 3,43 | 0,49 | 0,39 |
| | | Change in % | 59,65 | 76,08 | 0,00 | 82,43 | 0,00 | 79,93 | 0,00 | 78,32 | 82,68 | 459,07 | -60,84 | 38,86 |
| | 3 | Wet weight, start [g] | 1,11 | 1,11 | 1,11 | 1,11 | 1,11 | 1,11 | 1,11 | 1,11 | 1,11 | 10,00 | 1,11 | 0,00 |
| | | Wet weight, end [g] | 1,5 | 0,7 | 0 | 0,6 | 0,6 | 0,8 | 0 | 0 | 0,3 | 4,50 | 0,50 | 0,49 |
| | | Dry weight, end [g] | 0,2029 | 0,126 | 0 | 0,0919 | 0,0908 | 0,156 | 0 | 0 | 0,1044 | 0,77 | 0,09 | 0,07 |
| | | Daily growth rate total | 0,01 | -0,01 | -0,04 | -0,02 | -0,02 | -0,01 | -0,04 | -0,04 | -0,03 | -0,20 | -0,02 | 0,02 |
| | | Change in weight [g] | 1,2971 | 0,574 | 0 | 0,5081 | 0,5092 | 0,644 | 0 | 0 | 0,1956 | 3,73 | 0,41 | 0,42 |
| | | Change in % | 86,47 | 82,00 | 0,00 | 84,68 | 84,87 | 80,50 | 0,00 | 0,00 | 65,20 | 483,72 | -54,95 | 40,79 |
| | 4 | Wet weight, start [g] | 1,11 | 1,11 | 1,11 | 1,11 | 1,11 | 1,11 | 1,11 | 1,11 | 1,11 | 10,00 | 1,11 | 0,00 |
| | | Wet weight, end [g] | 1,1 | 0,2 | 0,3 | 0 | 0 | 0,5 | 0 | 0 | 0 | 2,10 | 0,23 | 0,37 |
| | | Dry weight, end [g] | 0,1426 | 0,0538 | 0,0911 | 0 | 0 | 0,1029 | 0 | 0 | 0 | 0,39 | 0,04 | 0,06 |
| | | Daily growth rate total | 0,00 | -0,03 | -0,03 | -0,04 | -0,04 | -0,02 | -0,04 | -0,04 | -0,04 | -0,28 | -0,03 | 0,01 |
| | | Change in weight [g] | 0,9574 | 0,1462 | 0,2089 | 0 | 0 | 0,3971 | 0 | 0 | 0 | 1,71 | 0,19 | 0,32 |
| | | Change in % | 87,04 | 73,10 | 69,63 | 0,00 | 0,00 | 79,42 | 0,00 | 0,00 | 0,00 | 309,19 | -78,98 | 41,01 |
| | 5 | Wet weight, start [g] | 1,11 | 1,11 | 1,11 | 1,11 | | | | | | 4,44 | 1,11 | 0,00 |
| | | Wet weight, end [g] | 3,1 | 4,8 | 3,8 | 2,4 | | | | | | 14,10 | 3,53 | 1,02 |
| | | Dry weight, end [g] | 0,3768 | 0,2659 | 0,3219 | 0,4492 | | | | | | 1,41 | 0,35 | 0,08 |
| | | Daily growth rate total | 0,07 | 0,13 | 0,10 | 0,05 | | | | | | 0,35 | 0,09 | 0,04 |
| | | Change in weight [g] | 2,7232 | 4,5341 | 3,4781 | 1,9508 | | | | | | 12,69 | 3,17 | 1,10 |
| | | Change in % | 87,85 | 94,46 | 91,53 | 81,28 | | | | | | 355,12 | 217,57 | 5,68 |

| Height measurements | | | Plant number 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Total | Average | Standard deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ´Balkonzauber' Tomato Plant | 1 | Height total, start [mm] | 190 | 200 | 220 | 200 | 280 | 240 | 310 | 210 | 200 | 2050 | 227,8 | 41,5 |
| | | Height aerial, start [mm] | 120 | 105 | 105 | 115 | 100 | 90 | 110 | 105 | 110 | 960 | 106,7 | 8,7 |
| | | Height roots, start [mm] | 70 | 95 | 115 | 85 | 180 | 180 | 200 | 105 | 90 | 1120 | 124,4 | 48,6 |
| | | Height total, end [mm] | 720 | 655 | 530 | 585 | 540 | 505 | 360 | 540 | 465 | 4900 | 544,4 | 104,2 |
| | | Height aerial, end [mm] | 370 | 375 | 360 | 425 | 320 | 285 | 210 | 340 | 325 | 3010 | 334,4 | 61,3 |
| | | Height roots, end [mm] | 350 | 280 | 170 | 160 | 220 | 220 | 150 | 200 | 140 | 1890 | 210,0 | 68,4 |
| | | Change in %, aerial height | 208,3 | 257,1 | 242,9 | 269,6 | 220,0 | 216,7 | 90,9 | 223,8 | 195,5 | 1925 | 213,9 | 51,8 |
| | | Change in %, total height | 278,9 | 227,5 | 140,9 | 192,5 | 92,9 | 110,4 | 16,1 | 157,1 | 132,5 | 1349 | 149,9 | 77,2 |
| | | Daily growth rate aerial | 8,9 | 9,6 | 9,1 | 11,1 | 7,9 | 7,0 | 3,6 | 8,4 | 7,7 | 73 | 8,1 | 2,1 |
| | | Daily growth rate total | 18,9 | 16,3 | 11,1 | 13,8 | 9,3 | 9,5 | 1,8 | 11,8 | 9,5 | 102 | 11,3 | 4,9 |
| | 2 | Height total, start [mm] | 100 | 170 | 190 | 220 | 200 | 160 | 210 | 260 | 190 | 1700 | 188,9 | 44,3 |
| | | Height aerial, start [mm] | 70 | 100 | 110 | 100 | 95 | 90 | 105 | 110 | 90 | 870 | 96,7 | 12,5 |
| | | Height roots, start [mm] | 30 | 70 | 80 | 120 | 105 | 70 | 105 | 150 | 100 | 830 | 92,2 | 34,5 |
| | | Height total, end [mm] | 190 | 245 | 210 | 200 | 220 | 215 | 230 | 240 | 215 | 1965 | 218,3 | 17,9 |
| | | Height aerial, end [mm] | 110 | 150 | 140 | 125 | 140 | 140 | 130 | 130 | 125 | 1190 | 132,2 | 11,8 |
| | | Height roots, end [mm] | 80 | 95 | 70 | 75 | 80 | 75 | 100 | 110 | 90 | 775 | 86,1 | 13,4 |
| | | Change in %, aerial height | 57,1 | 50,0 | 27,3 | 25,0 | 47,4 | 55,6 | 23,8 | 18,2 | 38,9 | 343 | 38,1 | 14,9 |
| | | Change in %, total height | 90,0 | 44,1 | 10,5 | -9,1 | 10,0 | 34,4 | 9,5 | -7,7 | 13,2 | 195 | 21,7 | 30,9 |
| | | Daily growth rate aerial | 1,4 | 1,8 | 1,1 | 0,9 | 1,6 | 1,8 | 0,9 | 0,7 | 1,3 | 11 | 1,3 | 0,4 |
| | | Daily growth rate total | 3,2 | 2,7 | 0,7 | -0,7 | 0,7 | 2,0 | 0,7 | -0,7 | 0,9 | 9 | 1,1 | 1,4 |
| | 3 | Height total, start [mm] | 190 | 180 | 240 | 280 | 210 | 250 | 220 | 200 | 220 | 1990 | 221,1 | 31,4 |
| | | Height aerial, start [mm] | 110 | 100 | 120 | 120 | 105 | 100 | 130 | 125 | 120 | 1030 | 114,4 | 11,0 |
| | | Height roots, start [mm] | 80 | 80 | 120 | 169 | 105 | 150 | 90 | 75 | 100 | 969 | 107,7 | 32,9 |
| | | Height total, end [mm] | 185 | 170 | 220 | 240 | 250 | 180 | 190 | 220 | 195 | 1850 | 205,6 | 28,0 |
| | | Height aerial, end [mm] | 95 | 85 | 110 | 150 | 100 | 95 | 90 | 120 | 115 | 960 | 106,7 | 20,0 |
| | | Height roots, end [mm] | 90 | 85 | 110 | 90 | 150 | 85 | 100 | 100 | 80 | 890 | 98,9 | 21,3 |
| | | Change in %, aerial height | -13,6 | -15,0 | -8,3 | 25,0 | -4,8 | -5,0 | -30,8 | -4,0 | -4,2 | -61 | -6,7 | 14,7 |
| | | Change in %, total height | -2,6 | -5,6 | -8,3 | -14,3 | 19,0 | -28,0 | -13,6 | 10,0 | -11,4 | -55 | -6,1 | 13,9 |
| | | Daily growth rate aerial | -0,5 | -0,5 | -0,4 | 1,1 | -0,2 | -0,2 | -1,4 | -0,2 | -0,2 | -3 | -0,3 | 0,6 |
| | | Daily growth rate total | -0,2 | -0,4 | -0,7 | -1,4 | 1,4 | -2,5 | -1,1 | 0,7 | -0,9 | -5 | -0,6 | 1,2 |
| | 4 | Height total, start [mm] | 230 | 230 | 300 | 280 | 280 | 205 | 260 | 210 | 200 | 2195 | 243,9 | 37,1 |
| | | Height aerial, start [mm] | 110 | 95 | 120 | 120 | 110 | 100 | 100 | 100 | 100 | 955 | 106,1 | 9,3 |
| | | Height roots, start [mm] | 120 | 135 | 180 | 160 | 170 | 105 | 160 | 110 | 100 | 1240 | 137,8 | 30,4 |
| | | Height total, end [mm] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,0 | 0,0 |
| | | Height aerial, end [mm] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,0 | 0,0 |
| | | Height roots, end [mm] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,0 | 0,0 |
| | | Change in %, aerial height | -100 | -100 | -100 | -100 | -100 | -100 | -100 | -100 | -100 | -900 | -100,0 | 0,0 |
| | | Change in %, total height | -100 | -100 | -100 | -100 | -100 | -100 | -100 | -100 | -100 | -900 | -100,0 | 0,0 |
| | | Daily growth rate aerial | -3,93 | -3,39 | -4,29 | -4,29 | -3,93 | -3,57 | -3,57 | -3,57 | -3,57 | -34 | -3,8 | 0,3 |
| | | Daily growth rate total | -8,2 | -8,2 | -10,7 | -10,0 | -10,0 | -7,3 | -9,3 | -7,5 | -7,1 | -78 | -8,7 | 1,3 |
| | 5 | Height total, start [mm] | 220,4 | 220,4 | 220,4 | 220,4 | * | | | | | 882 | 220,4 | 0,0 |
| | | Height aerial, start [mm] | 90 | 90 | 90 | 110 | | | | | | 380 | 95,0 | 10,0 |
| | | Height roots, start [mm] | | | | | | | | | | | | |
| | | Height total, end [mm] | 285 | 424 | 405 | 370 | | | | | | 1484 | 371,0 | 61,5 |
| | | Height aerial, end [mm] | 145 | 224 | 195 | 190 | | | | | | 754 | 188,5 | 32,6 |
| | | Height roots, end [mm] | 140 | 200 | 210 | 180 | | | | | | 730 | 182,5 | 31,0 |
| | | Change in %, aerial height | 61,1 | 148,9 | 116,7 | 72,7 | | | | | | 399 | 99,8 | 40,5 |
| | | Change in %, total height | 29,3 | 92,4 | 83,7 | 67,9 | | | | | | 273 | 68,3 | 27,9 |
| | | Daily growth rate aerial | 2,0 | 4,8 | 3,8 | 2,9 | | | | | | 13 | 3,3 | 1,2 |
| | | Daily growth rate total | 2,3 | 7,3 | 6,6 | 5,3 | | | | | | 22 | 5,4 | 2,2 |

**Height measurements**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New Zealand Spinach | 1 | Height total, start [mm] | 105 | 120 | 110 | 105 | 110 | 135 | 120 | 110 | 110 | 1025 | 113,9 | 9,6 |
| | | Height aerial, start [mm] | 60 | 40 | 25 | 45 | 30 | 65 | 50 | 40 | 45 | 400 | 44,4 | 12,9 |
| | | Height roots, start [mm] | 45 | 80 | 85 | 60 | 80 | 70 | 70 | 70 | 65 | 625 | 69,4 | 12,1 |
| | | Height total, end [mm] | 260 | 400 | 290 | 295 | 330 | 560 | 420 | 195 | 160 | 2910 | 323,3 | 122,7 |
| | | Height aerial, end [mm] | 80 | 110 | 70 | 100 | 145 | 200 | 140 | 65 | 65 | 975 | 108,3 | 45,9 |
| | | Height roots, end [mm] | 180 | 290 | 220 | 195 | 185 | 360 | 280 | 130 | 95 | 1935 | 215,0 | 83,0 |
| | | Change in %, aerial height | 33,3 | 175,0 | 180,0 | 122,2 | 383,3 | 207,7 | 180,0 | 62,5 | 44,4 | 1389 | 154,3 | 107,9 |
| | | Change in %, total height | 147,6 | 233,3 | 163,6 | 181,0 | 200,0 | 314,8 | 250,0 | 77,3 | 45,5 | 1613 | 179,2 | 83,9 |
| | | Daily growth rate aerial | 0,7 | 2,5 | 1,6 | 2,0 | 4,1 | 4,8 | 3,2 | 0,9 | 0,7 | 21 | 2,3 | 1,5 |
| | | Daily growth rate total | 5,5 | 10,0 | 6,4 | 6,8 | 7,9 | 15,2 | 10,7 | 3,0 | 1,8 | 67 | 7,5 | 4,1 |
| | 2 | Height total, start [mm] | 100 | 110 | 130 | 135 | 110 | 110 | 150 | 90 | 115 | 1050 | 116,7 | 18,5 |
| | | Height aerial, start [mm] | 45 | 30 | 50 | 55 | 55 | 40 | 50 | 30 | 55 | 410 | 45,6 | 10,1 |
| | | Height roots, start [mm] | 55 | 80 | 80 | 80 | 55 | 70 | 100 | 60 | 60 | 640 | 71,1 | 15,2 |
| | | Height total, end [mm] | 110 | 115 | x | 145 | x | 120 | x | 100 | 125 | 715 | 119,2 | 15,3 |
| | | Height aerial, end [mm] | 35 | 45 | | 55 | | 40 | | 30 | 30 | 235 | 39,2 | 9,7 |
| | | Height roots, end [mm] | 75 | 70 | | 90 | | 80 | | 70 | 95 | 480 | 80,0 | 10,5 |
| | | Change in %, aerial height | -22,2 | 50,0 | -100,0 | 0,0 | -100,0 | 0,0 | -100,0 | 0,0 | -45,5 | -318 | -35,3 | 54,6 |
| | | Change in %, total height | 10,0 | 4,5 | | 7,4 | | 9,1 | | 11,1 | 8,7 | 51 | 8,5 | 2,3 |
| | | Daily growth rate aerial | -0,4 | 0,5 | -1,8 | 0,0 | -2,0 | 0,0 | -1,8 | 0,0 | -0,9 | -6 | -0,7 | 0,9 |
| | | Daily growth rate total | 0,4 | 0,2 | | 0,4 | | 0,4 | | 0,4 | 0,4 | 2 | 0,3 | 0,1 |
| | 3 | Height total, start [mm] | 120 | 130 | 110 | 110 | 130 | 150 | 150 | 110 | 110 | 1120 | 124,4 | 16,7 |
| | | Height aerial, start [mm] | 65 | 65 | 30 | 35 | 40 | 40 | 25 | 50 | 35 | 385 | 42,8 | 14,4 |
| | | Height roots, start [mm] | 55 | 65 | 80 | 75 | 90 | 110 | 125 | 60 | 75 | 735 | 81,7 | 23,2 |
| | | Height total, end [mm] | 145 | 140 | x | 100 | 120 | 130 | x | x | 110 | 745 | 124,2 | 17,4 |
| | | Height aerial, end [mm] | 35 | 30 | | 20 | 30 | 35 | | | 20 | 170 | 28,3 | 6,8 |
| | | Height roots, end [mm] | 110 | 110 | | 80 | 90 | 95 | | | 90 | 575 | 95,8 | 12,0 |
| | | Change in %, aerial height | -46,2 | -53,8 | -100,0 | -42,9 | -25,0 | -12,5 | -100,0 | -100,0 | -42,9 | -523 | -58,1 | 33,7 |
| | | Change in %, total height | 20,8 | 7,7 | | -9,1 | -7,7 | -13,3 | | | 0,0 | -2 | -0,3 | 12,7 |
| | | Daily growth rate aerial | -1,1 | -1,3 | -1,1 | -0,5 | -0,4 | -0,2 | -0,9 | -1,8 | -0,5 | -8 | -0,9 | 0,5 |
| | | Daily growth rate total | 0,9 | 0,4 | | -0,4 | -0,4 | -0,7 | | | 0,0 | 0 | 0,0 | 0,6 |
| | 4 | Height total, start [mm] | 140 | 105 | 110 | 120 | 150 | 130 | 140 | 135 | 125 | 1155 | 128,3 | 14,8 |
| | | Height aerial, start [mm] | 70 | 30 | 35 | 40 | 65 | 55 | 45 | 45 | 50 | 435 | 48,3 | 13,2 |
| | | Height roots, start [mm] | 70 | 75 | 75 | 80 | 85 | 75 | 95 | 90 | 75 | 720 | 80,0 | 8,3 |
| | | Height total, end [mm] | 135 | 85 | 115 | x | x | 125 | x | x | x | 460 | 115,0 | 21,6 |
| | | Height aerial, end [mm] | 25 | 15 | 25 | | | 30 | | | | 95 | 23,8 | 6,3 |
| | | Height roots, end [mm] | 110 | 70 | 90 | | | 95 | | | | 365 | 91,3 | 16,5 |
| | | Change in %, aerial height | -64,3 | -50,0 | -28,6 | -100,0 | -100,0 | -45,5 | -100,0 | -100,0 | -100,0 | -688 | -76,5 | 29,3 |
| | | Change in %, total height | -3,6 | -19,0 | 4,5 | | | -3,8 | | | | -22 | -5,5 | 9,8 |
| | | Daily growth rate aerial | -1,6 | -0,5 | -0,4 | | | -0,9 | | | | -3 | -0,8 | 0,6 |
| | | Daily growth rate total | -0,2 | -0,7 | 0,2 | | | -0,2 | | | | -1 | -0,4 | 0,4 |
| | 5 | Height total, start [mm] | 120,8 | 120,8 | 120,8 | 120,8 | * | | | | | 483 | 120,8 | 0,0 |
| | | Height aerial, start [mm] | 40 | 45 | 25 | 34 | | | | | | 144 | 36,0 | 8,6 |
| | | Height roots, start [mm] | | | | | | | | | | | | |
| | | Height total, end [mm] | 100 | 115 | 100 | 85 | | | | | | 400 | 100,0 | 12,2 |
| | | Height aerial, end [mm] | 45 | 45 | 55 | 35 | | | | | | 180 | 45,0 | 8,2 |
| | | Height roots, end [mm] | 55 | 70 | 45 | 50 | | | | | | 220 | 55,0 | 10,8 |
| | | Change in %, aerial height | 12,5 | 0,0 | 120,0 | 2,9 | | | | | | 135 | 33,9 | 57,7 |
| | | Change in %, total height | -17,2 | -4,8 | -17,2 | -29,7 | | | | | | -69 | -17,2 | 10,1 |
| | | Daily growth rate aerial | 0,18 | 0,00 | 1,07 | 0,04 | | | | | | 1 | 0,3 | 0,5 |
| | | Daily growth rate total | -0,7 | -0,2 | -0,7 | -1,3 | | | | | | -3 | -0,7 | 0,4 |

** P5 (soil plants) start weight is the average of other parallels start weight, as start weights were missing for soil plants.

Date: 26.05.2020

| **Visual check of plants** | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ´Balkonzauber' Tomato Plants | 1 | Branches: | 15 | 11 | 10 | 14 | 10 | 10 | 6 | 11 | 13 |
| | | Leaves: | | | | | | | | | |
| | | Color: | Fresh green. | | | | | | | | |
| | | State of plant: | The plants in this parallel thrived. Huge plants with extreme root development. Fresh green color and almost no discolored or dried leaves. Plants developed flowerbuc and some started flowering. Plant 7 did not grow as well as others. A small plant, some dry and discolored leaves at lower branches. | | | | | | | | |
| | 2 | Branches: | 7 | 6 | 7 | 6 | 6 | 7 | 6 | 7 | 6 |
| | | Leaves: | | | | | | | | | |
| | | Color: | All plants are green and a bit yellow. Older leaves have some discoloring. | | | | | | | | |
| | | State of plant: | Plants in this parallel grew well and lots of new roots started developing. These were still too short to reach the film, but if they were left for a week two more, growth might increase rapidly. Flowerbuds developed. Some dry leaves and miscolored leaves. | | | | | | | | Algeagrowth on roots. |
| | 3 | Branches: | 3 | 4 | 3 | 4 | 5 | 4 | 4 | 4 | 4 |
| | | Leaves: | | | | | | | | | |
| | | Color: | All plants are green and yellow. | | | | | | | | |
| | | State of plant: | Most plants has some dry or dead leaves. But newer leaves are greener and seem okay. | | | | | | | | Algeagrowth on roots. |
| | 4 | Branches: | x | x | x | x | x | x | x | x | x |
| | | Leaves: | | | | | | | | | |
| | | Color: | | | | | | | | | |
| | | State of plant: | All plants dead. Tried to plant new plants, but they also started drooping and seemed to be dying. | | | | | | | | |
| | 5 | Branches: | 8 | 8 | 8 | 8 | | | | | |
| | | Leaves: | | | | | | | | | |
| | | Color: | Fresh green. | | | | | | | | |
| | | State of plant: | Good looking plants. Some dead leafes on lowest branches, but newer leaves look healthy. | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| New Zealand Spinach | 1 | Branches: | 4 | 4 | 1 | 3 | 4 | 10 | 7 | 1 | 3 |
| | | Leaves: | 21 | 21 | 10 | 11 | 23 | 66 | 35 | 10 | 15 |
| | | Color: | Fresh green. | | | | | | | | |
| | | State of plant: | All plants look very good. They are much bigger than in other parallels. Plant nr. 6 has grown extremly well and has a huge root system. There is a b difference in growth between the plants in this parallel. | | | | | | | | Algeagrowth on roots. |
| | 2 | Branches: | 1 | 1 | x | 1 | x | 1 | x | 1 | 1 |
| | | Leaves: | 3 | 4 | | 5 | | 5 | | 6 | 5 |
| | | Color: | All plants light green and with some yellow leaves. | | | | | | | | |
| | | State of plant: | Plants in this parallel are small in general. | | | | | | | | |
| | 3 | Branches: | 1 | 1 | x | 1 | 1 | 1 | x | 1 | 1 |
| | | Leaves: | 5 | 4 | | 3 | 4 | 4 | | 3 | 2 |
| | | Color: | All plants green and light green. Plant nr.8 had a more brown color. | | | | | | | | |
| | | State of plant: | Plants in this parallel are in general small. Salt can be observed on leaves. Two plants are dead and nr. 8 seems to be dying. | | | | | | | | |
| | 4 | Branches: | 1 | 1 | 1 | x | x | 1 | x | x | x |
| | | Leaves: | 4 | 2 | 3 | | | 2 | | | |
| | | Color: | Plants in this parallel are in general light green. | | | | | | | | |
| | | State of plant: | Plants are rather small and several are drooping. | | | | | | | | |
| | 5 | Branches: | 1 | 2 | 1 | 1 | | | | | |
| | | Leaves: | 8 | 9 | 7 | 6 | | | | | |
| | | Color: | Green and light green in edges. | | | | | | | | |
| | | State of plant: | Very good. Plants are growing well and looks very healthy. | | | | | | | | |

NTNU

Norwegian University of
Science and Technology