Hydroponic cultivation

– Cultivation in Water That Saves Water?

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Abstract

One of the largest contributors to rising sea levels is the high rate at which water withdrawals are made worldwide, amassing a volume of 4 quadrillion liters of water annually. It has shown that agricultural production is the largest contributor to these water withdrawals. Therefore the aim of this project was to study the differences in water consumption between hydroponic- and traditional cultivation methods in order to ascertain the advantages and disadvantages of these two farming techniques. By conducting four different experimental cultivations it was determined that water savings as large as 55% could be made by conducting hydroponic cultivations rather than traditional ones of that. With this result and the gathered information concerning the harvested mass, it was concluded that water savings of up to 33% could be made without affecting the mass of the harvest made from the farm used. It was also concluded that the harvest of the hydroponic cultivation was 52% larger per liter of water used than the traditional cultivation.

Keywords:

water withdrawals *hydroponic* *agriculture* *Pak Choi*

List of abbreviations

Abbreviation	**Definition**
DWC	deep water culture
RDWC	recirculating deep water culture
ESG	environmental, social and governance
LED	light emitting diode
UN	United Nations

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1. Introduction

Hydroponic cultivations are cultivations that are conducted in a nutrient solution as the primary source of nutrition. In hydroponic cultivation, the plants are partially submerged in an enclosed water bath, meaning that large amounts of water can be saved (Hatter, Williams & Purdy Insurance, 2014).

1.1 Purpose of the report

The purpose of this report is to investigate the scale of water savings that can be made through hydroponic cultivation in comparison to traditional cultivation. Then, concerning the water savings, the purpose is to compare the growth rate and mass of the crops of the two methods to then comparatively analyze both cultivational techniques to determine possible advantages and disadvantages with these. This study is conducted to gain a deeper insight into the hydroponic cultivation technique and deep water cultures. Based on the aforementioned sub-objectives, the results obtained will then be analyzed from a societal perspective for further in-depth study.

1.2 Research questions

- ➢ How much water is saved in hydroponic cultivation compared to traditional cultivation, and what is the water loss caused by?
- ➢ How do the growth rate and the mass of yield in each cultivation differ concerning water consumption, what causes these differences?
- ➢ Which are the most obvious advantages and disadvantages of hydroponic- and traditional cultivations?
- ➢ How can the results be observed from a societal perspective?

2. Theoretical background

2.1 The concept of hydroponics

Hydroponic cultivation is a branch of hydro cultures and a form of cultivation where crops grow submerged in a water bath containing a nutrient solution. Hydroponic cultivation can be carried out with or without a lack of soil, however, when cultivating terrestrial plants, roots are often physically supported by a chemically non-reactive substance to establish the root system. Plants that are grown hydroponically have uniquely designed root systems as the dynamics of the water affect the root growth. The form of cultivation was thus named hydroponics as the term literally means “water working” (Gericke, 1945).

The vital nutrient solution can be prepared naturally and artificially. For the natural method, the aquaponic cultivation principle is used where animal aquaculture is combined with plant cultivation (Baganz et al., 2021). For this cultivation method, different forms of fish are combined with plants. The fishes in the system emit ammonia through their feces, which is oxidized to nitrites with the help of Nitrosomonas bacteria (Hemmaodlat, 2013; Karolinska Institutet [KI], n.d.). The nitrites are then neutralized by Nitrospira bacteria which convert them into nitrates, which in turn become utilized by the plants as a natural means of fertilization (Hemmaodlat, 2013). This cycle can be seen in ***Figure 1***.

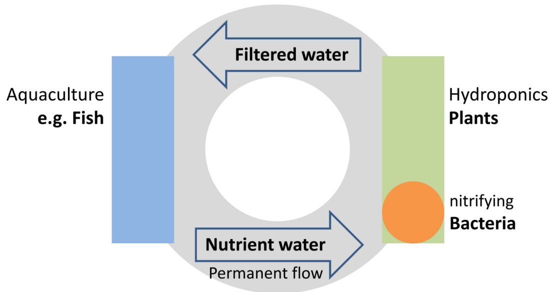

Figure 1

Schematic sketch explaining the basics of aquaponics (Baganz et al., 2021).

Nutrition solutions that are produced artificially are based on the knowledge of Knop’s solution. Knop’s solution is a water-based solution containing the main inorganic constituents needed for the growth of higher plants. These essential nutrients consist of calcium nitrate, potassium nitrate, magnesium sulfate, potassium dihydrogen phosphate, and potassium chloride (Smith, 2000). The knowledge regarding Knop’s solution is based on studies made by Wilhelm Knop, a German agrochemist and a pioneer in water cultures (Marschner, 1995). The function that a nutrient solution fulfills in hydroponic cultivation can be compared to the function that the nutrients in the substrate fulfill for crops that grow in soil (Trees, 2021). Generally, a small amount of the concentrated nutrient solution is mixed into the water and brought to the plants in dilute form (Hjelm, 2018).

Hydroponic cultivations are usually divided into active and passive hydro systems. The two systems are distinguished by the way the nutrient solution comes into contact with the plants. In passive hydro systems, watering of nutrient solution is done either manually or by the nutrient solution coming into contact with the roots of the plants through the capillary force. Active hydro systems are on the other hand characterized by various pumps that bring the nutrient solution to the roots (Hydrogarden, 2020).

2.1.1 Deep water culture

DWC is one of the most frequently used hydroponic systems. It is mainly used for the cultivation of different lettuces and herbs (Trees, 2022). DWC is a passive hydro system (Hydrogarden, 2020) where the roots of the plants are immersed in a deep bath of solution containing water and a dilute nutrient solution. Larger tubs or crates are often used for this cultivation method, which results in a stability buffer in nutrient content and pH (Trees, 2022). As plants grow immersed in water, oxygen deficiency can easily occur, which in turn can lead to the plants dying as a result of root decay. Therefore, an air pump is essential in DWC systems as it oxygenates the water and contributes to the circulation of oxygen and nutrients in the cultivation reservoir, which streamlines the nutrient uptake of the plants. This often results in abundant growth in plants grown in DWC systems (Trees, 2022).

The DWC system itself has also been branched and occurs in different variants, including *bubbleponics*, which is a DWC system where a water pump is added, watering the plants while submerged in water. There is also a system named the *Kratky method* which is considerably low-tech since it does not require an air pump. The system instead relies on the air around the roots for oxygen absorption. Finally, there is also the so-called RDWC which is a system based on the water circulating through several DWC systems connected to a central reservoir. This system is thus better adapted for large-scale cultivations as all parameters can be easily controlled and measured from the central reservoir (Trees, 2022).

2.2 The problematic water consumption

The main disadvantage of traditional cultivation techniques is that water consumption is not being taken into account, which has become a very significant problem as water consumption has increased by roughly 500% since 1901 (Our World in Data, 2018). The increased consumption is mainly due to so-called water outlets, which are facilities where groundwater and surface water is withdrawn out of their origin to be used for various purposes. The water is kept above the groundwater level and is then considered to be lost (Organization for Economic Co-operation and Development [OECD], 2021). In 2021, the world consumed 4 trillion cubic meters of water via these water outlets (Worldometer, 2021), 72% of which were used by the agricultural industry, see ***Figure 2*** (United Nations, 2021).

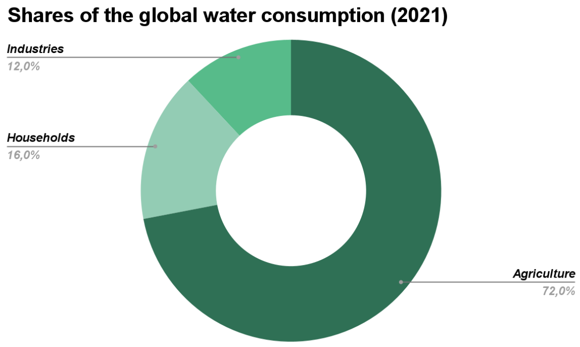

Figure 2
Data assembled by the United Nations displaying the global water consumption (2021)

These water withdrawals are damaging as they can lead to unevenness in the soil surface above the groundwater reservoirs and contamination of saltwater in said reservoirs (Kumar & Yaashikaa, 2019). However, the most problematic consequence of water withdrawals is the fact that they raise sea levels as the water that is pumped up eventually reaches the oceans. It has been found that the withdrawals from the groundwater reservoirs, which make up a majority of the total water withdrawals, raise the sea levels on earth by approximately 0.6 mm annually (Mascarelli, 2012; Lovett, 2012), equaling 16% of the yearly total increase in sea levels (Stockholms Stad, 2022).

2.3 Modern hydroponics

The growing interest in improving planetary health has contributed to the birth of modern hydroponics. One of the leading companies in Sweden that conduct hydroponic cultivations at an industrial level is Urban Oasis. This company conducts large vertical hydroponic cultivation in a rock chamber in Stockholm. These vertical farms use data software that automatically maximizes crop yield. Since cultivation is carried out sanitarily, no pesticides are needed to protect the crops against pathogens, which in combination with the low water consumption makes Urban Oasis a more environmentally friendly alternative (TV4 Nyheterna, 2021). Another leading company that actively works with hydroponic cultivation is the ESG company SweGreen. As the company's business model aims at sustainable development, its cultivation is conducted vertically and sanitarily, similar to Urban Oasis. The biggest noticeable difference, however, is that the company SweGreen is a so-called "hyper-local" company. This means that the company conducts cultivation in the store where the company's products are sold. The combination of the company's hydroponic, sanitary, and vertical cultivations and the fact that these are conducted "hyper-locally" contribute to a low carbon footprint, a non-toxic diet, and also a very low water consumption with minimized water loss (SweGreen, n.d.).

2.4 Crops

2.4.1 Basil

Basil (*Ocimum basilicum*) is an herb belonging to the mint genus (Western Institute for Food Safety & Security [WIFSS], 2016). The seeds germinate best at a temperature of around 20°C, and abundant growth can occur on a spectrum between 7-27°C. Basil is very sensitive to drought, therefore the crop requires a moist substrate. The plant thrives best in soil with high biomatter and good drainage ability. For optimal growth of the herb, the pH should be 6.4, however, the plant can grow in a spectrum between pH 4.3-8.2 (Department of Agriculture, Forestry and Fisheries, 2012). Hydroponics also makes it possible to easily optimize growing conditions according to the needs of the basil (Abass et al., 2021)

2.4.2 Pak Choi

Pak Choi (*Brassica rapa subsp. Chinensis*), is a hardy crop that provides abundant growth in temperatures between 13-24°C (Storey, 2016). A larger mass of Pak Choi can also be extracted when the light supply is high (Kossowski & Wolfe, 1997). Pak Choi benefits the most from a well-drained substrate while the water supply is regular (Government of The Republic of Trinidad and Tobago, 2009). The growth of Pak Choi is most effective in the range of pH 5.5-7, however, it is sensitive to pH changes (Pennsylvania State University [PSU], n.d.). Under optimal conditions, the seeds germinate in about 1-2 days and reach full-grown size after about 40-60 days (Government of the Republic of Trinidad and Tobago, 2009; Huggins et al., 1992).

3. Methodology

3.1 Literary research

Literature studies and preparations for the two cultivational experiments took place by obtaining thorough knowledge from unscientific sources where hydroponic cultivations were discussed. When better knowledge regarding the subject had been obtained, advanced and scientific sources were used. In addition, a very short dialogue was also held with the company SweGreen, which in turn laid the foundation for the choice of crops for the hydroponic cultivation set-up.

3.2 Experiment design

3.2.1 Traditional cultivations

The traditional cultivation was designed by filling ten plastic pots with soil. For each pot, the sowing soil was mixed abundantly with water to obtain properly moistened soil. When sowing the seeds, the depth of a cultivation plug was used as a reference to ensure that the pits of the sowing soil would have the same proportions as the pits of the cultivation plugs. The pits were then made using a wooden stick in which four Pak Choi seeds were placed. Finally, the plastic pots were placed in a deep tray that was placed in a window facing west.

The traditional cultivation with LED lighting was set up according to the same method used during the first set-up. The only difference was that a luminaire was placed on the tray so that a 15 W LED lighting could illuminate the pots. The entire set-up was then placed in a room where access to light was lacking, excluding the light emitted by the LED lighting.

3.2.2 Hydroponic cultivations

The pilot experiment of hydroponic cultivation was carried out with the hydroponic cultivation technique of deep water culture (DWC), see ***Figure 3***.

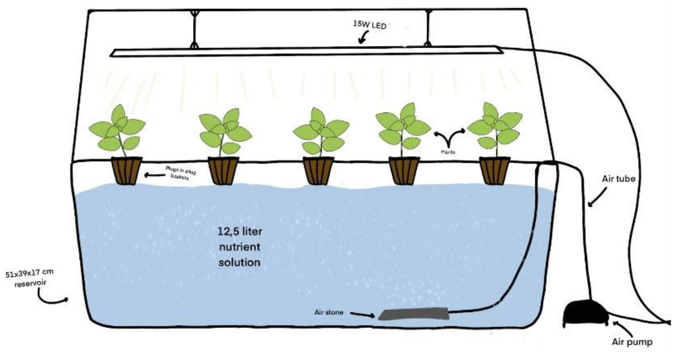

Figure 3

A simplified schematic cross-section of the hydroponic cultivation arrangement.

For the pilot experiment, 10 holes were made in the lid of the box for all cultivation plugs. Then the box was gradually filled with water until the water surface touched the bottom of the plug basket. A hole for the silicone hose was then drilled above the water surface, which connected the air pump to the air stone. After this, the air stone was placed in the water with the air pump next to the device, and finally, 25 cm^3 of the nutrient solution was added to the water.

Thereafter, the cultivation plugs were placed in the plug baskets. Eight cultivation plugs received four basil seeds and the remaining two received four Pak Choi seeds each. Finally, a luminaire with a 15W LED lamp was placed on top of the lid. For the main hydroponic cultivation, the only real difference was that only Pak Choi seeds were sown. In addition, 1000 cm^3 of water was added during the experiment.

3.2.3 Data collection

When collecting data, values were collected for the plants' height, mass, and water loss. The height was measured every school day until the day of harvest, while the mass was measured on harvest day. The collected data was then analyzed in Google Spreadsheets. The water consumption of the traditional cultivations was obtained by summing the total amount of water supplied, while the water loss of the hydroponic cultivation was obtained by measuring the volume of water that evaporated during the cultivation period. This was done by subtracting the amount of water left in the reservoir at the end of the trial from the water added at the start of the trial. Finally, all data obtained were used to generate linear regressions and comparisons for the growth of the different cultures in Google Spreadsheets.

4. Results

4.1 Hydroponic cultivation - pilot trial

During the pilot trial of the hydroponic cultivation, as previously mentioned, Pak Choi seeds were sown in two of the cultivation plugs, and in the remaining eight basil was sown. In all plugs, the germination rate was 100%. After three days, the Pak Choi had germinated and started to grow and develop widespread heart leaves, while the basil was still significantly behind. When a week had passed, the basil also started to develop heart leaves, and a day later all the plugs had developed root systems. On the tenth day, a few more leaves could be observed in all Pak Choi plants. By day 22, the leaves of the basil plants had fully unfolded and were no longer shrunken, and the Pak Choi plants were large and full-bodied. On day 25, all plants were harvested, with which most results could be obtained, then all results were summarized. Based on this method, various results could be obtained. The growth for the two types of crops can be seen in ***Figure 4***, while the result for the mass of the plants can be found in ***Figure 5***. In addition, the result for the cultivation's water consumption could be determined to be 1.39 l.

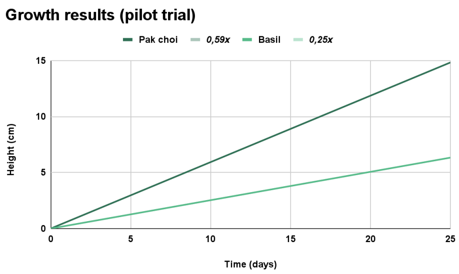

Figure 4
The diagram displays the Pak Choi- and basil growth during the days on which measurements were collected.

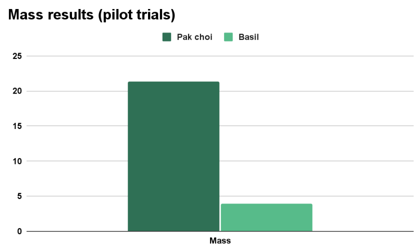

Figure 5
The diagram displays the differences in mass between Pak Choi and basil.

4.2 Hydroponic cultivation - main trial

The main experiment of the hydroponic cultivation consisting of only Pak Choi seeds gave a germination rate of 95%. Five days after sowing, widespread heart leaves had begun to develop. The next day, some plugs had root systems. By the eighteenth day, all the plugs had well-developed root systems and larger leaves. On day 21, all plants were harvested. All of the plants were also weighed during the harvesting process, and it was found that the total mass of the plants was 23.9 g. The water loss for hydroponic cultivation was 2.006 l. Hence, the cultivation gave 10.8 g Pak Choi per liter of consumed water. At the harvest, it emerged that the total height for all plants was 91 cm. By using the "LINEST" function in Google Spreadsheets, it could also be concluded that the growth per day for Pak Choi was 4.17 cm/day. Based on this, a value for the growth of the cultivation concerning water consumption was also determined, this was found to be 2.1 (cm/day)/l, and a value for the height production with regard to water consumption was calculated to be 45.4 cm/l.

4.3 Traditional cultivation - sunlight

The reference cultivation for the traditional cultivation of Pak Choi with sunlight as the light source gave a germination rate of 87.5%. Five days after the day of planting, it could also be observed in the traditional cultivation that most of the Pak Choi seeds had germinated and started to grow. By this time, only smaller heart leaves had begun to develop. On the last day of cultivation, the plants were admittedly relatively long, but remarkably small. On this day, the total height of the crops was 78.6 cm. Measurements showed that the total mass was 1.4 g. It could also be determined that the growth for the crop was 4.5 cm/day, whereas the average growth rate per plant was 0.45 cm/day. It was also found that the mass harvest for the cultivation with regard to water consumption was 0.3 g/l. The growth rate per day in the cultivation with regard to water consumption was 1.0 (cm/day)/l and the cultivation gave 17.5 cm height/l of water.

4.4 Traditional cultivation - main trial

In the main cultivation of the traditional kind, on December 9, 2021, 40 Pak Choi seeds were sown. In this culture, the germination rate was 93%. By the fifth day, 81% of the seeds had germinated. The remaining seeds had not yet germinated by this time. However, two days later, smaller sprouts began to appear even in the pots that germinated more slowly. On day 17, the differences between the slow seeds and the other pots began to even out. On the day of harvest, nine of the plants were not differentiable from each other, however, one of the Pak Choi plants was smaller than the other nine due to its long germination time. When the cultivation was complete, several measured values could be collected and compiled. The growth rate of the traditional cultivation was determined to be 5.2 cm/day or 0.52 (cm/day)/plant. The cultivation produced a total of 24.1 cm of growth/l of water during three weeks. Values for the mass of all Pak Choi plants were found to be 32.1 g, calculations determined that the cultivation produced 7.3 g/l of water.

4.5 Comparative analysis between the main trials

During the project, clear differences in various aspects were observed. The hydroponic culture (21.7 g) gave 32% less mass than the traditional culture (32.1 g), see ***Figure 6***. The growth of the hydroponic culture (4.2 cm/day) was 19% less than the traditional (5.2 cm/day), see ***Figure 7***, and the height in the hydroponic cultivation (91 cm) was 16% less than the traditional cultivation (108.5 cm), see ***Figure 8***.

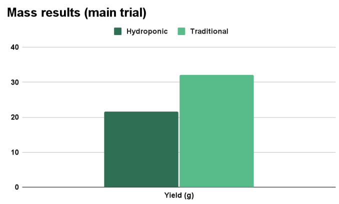

Figure 6
Differences in the mass of the yield.

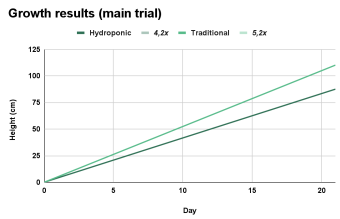

Figure 7
Differences in growth.

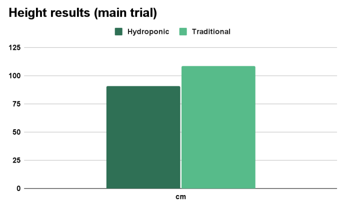

Figure 8
Differences in height of the yield.

The hydroponic cultivation produced on average 52% more harvested mass per liter of water consumed compared to the traditional cultivation, see ***Figure 9***. Each liter of water also gave 75% more growth in the hydroponic cultivation, see ***Figure 10***. The hydroponic cultivation gave the largest difference in height per liter of water where it produced 88% more than the traditional cultivation, see ***Figure 11***.

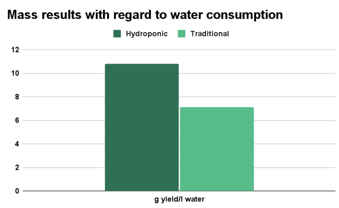

Figure 9
Differences in the mass of the yield with regard to water consumption.

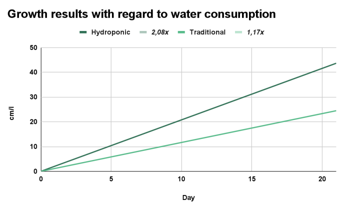

Figure 10
Differences in growth with regard to water consumption.

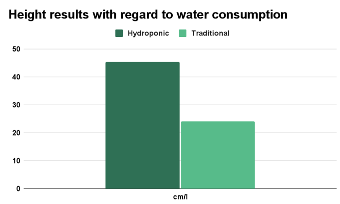

Figure 11
Differences in height with regard to water consumption.

5. Discussion

5.1 Hydroponic cultivation - pilot trial

The pilot trial of the hydroponic cultivation technique DWC was carried out to gather knowledge and experience in the cultivation technique. The basil could be excluded after the pilot cultivation as the germination time of Pak Choi was considerably shorter, which gave clearer results. The rapid growth of Pak Choi also meant that the growing period for the main crop could be shortened to 21 days. In addition to this, the pilot cultivation also made it possible to test the practical function of the setup, since the reservoir and the lid that held the plugs were entirely self-designed. The pilot experiment was thus used only for learning purposes.

The reservoir is also a central point of justification, as its shape and color were chosen deliberately and carefully. The shape and color were chosen as ten plugs could fit in the reservoir and to exclude the growth of algae and cyanobacteria as they can negatively affect the growth. Therefore, a black box was chosen to counteract the light entry as much as possible. According to Kossowski and Wolfe (1997), Pak Choi grows better with a larger light supply and thus the cultivation was given 16 light hours/day.

5.2 Traditional cultivation - sunlight

The original purpose of the traditional cultivation was to imitate the conditions prevailing when traditional cultivation is conducted on a large scale, hence no LED lighting was used. Initially, the purpose was to review how large-scale hydroponic cultivations are conducted compared to how large-scale traditional cultivations are conducted. When comparing hydroponic and traditional cultivation, unrealistic results were obtained due to a lack of sunlight as the traditional cultivation was conducted in the winter with short days and few hours of sunshine. This led to a large number of errors which made it impossible to classify the results as reasonable. The main reason why these errors occured was the fact that the hydroponic cultivation had received larger amounts of light compared to the traditional cultivation. With the failed attempt in mind, the decision was made to make a new cultivation that was designed identically to the previous one, except that LED lighting over the pots also would be included in the setup. Thus, the light as a source of error could be disregarded when the two cultures were given an indifferent light supply.

5.3 Discussing the comparative analysis

After the main experiment of the cultivations had been made, most conclusions could be drawn about the two cultivation techniques. The first of these was that the water loss was significantly greater in the traditional cultivation, it could be determined that the water consumption of the hydroponic cultivation was 55.4% less compared to the traditional cultivation. This significant difference in water consumption is due to the fact that the area of the traditional cultivation where evaporation could take place was about ten times as large as the correspondent area in the hydroponic cultivation.

The differences obtained can for the most part be linked to the fact that the hydroponic cultivation was conducted in a slightly cooler environment than the traditional cultivation. This in turn can be linked to the facts reported by Storey (2016), who points out that optimal growth for Pak Choi is obtained at a temperature between 13-24°C. The higher part of this spectrum results in more abundant growth as a result of more added heat energy. An additional influencing factor is the nutrients, as nutrient never were added to any of the crops during the cultivation experiment. Therefore, there is a slight risk that the hydroponic nutrient solution might have diminished during the experiment. This could also have been a cause of the different growths despite the similar conditions, but no such measurements were made. Despite the unfavorable results for hydroponic cultivation, it turned out that all results were to the advantage of this cultivation in terms of water consumption.

This shows the great advantage of hydroponics, namely water consumption. Despite the initial unfavorable results, it could be determined that the production, in every aspect, with regard to water consumption was considerably higher. This means that water consumption can be significantly reduced when cultivation is conducted hydroponically since the design of the cultivation allows the majority of the evaporated water to condense and fall back into the reservoir.

5.2.1 Advantages and disadvantages

The great advantage of hydroponic systems is that the form of cultivation is ecologically sustainable since it consumes less water. As hydroponic cultivation is carried out in closed systems, it becomes easy to work in a sterile environment without pesticides. In addition, parameters can easily be controlled to promote growth and prevent the spread of fertilizers. In this aspect, traditional crops are significantly worse as they release pesticides and fertilizers into nature, which is ecologically harmful as nature is damaged by these emissions. Hydroponic cultivation also saves large amounts of water, which makes the cultivation technology economically favorable since less water is used per harvest unit. The fact that hydroponics is so space-efficient and that these cultivations can be conducted vertically means that they can be conducted hyperlocally, which reduces shipping costs and emissions. As hydroponic setups also provide an abundant harvest, hydroponics can enable self-sufficient farming for certain foods. This would reduce carbon dioxide emissions and the costs for private households as well.

In order to design the advanced hydroponic systems that are required for larger scale cultivation, highly developed technology is usually required, which entails a large initial construction cost. In addition, energy and maintenance costs are also relatively large for hydroponic cultivations that are conducted on a large scale. As a result, financial resources become the biggest disadvantage of growing hydroponically. This instead, is an advantage for traditional farms whose expenses are less.

5.2.2 Hydroponics in a global perspective

When the results were applied from a broader and global perspective, approximate values for the theoretical water savings made by hydroponics could be calculated. It was then concluded that the hydroponic cultivation technique in theory could reduce global water consumption by 1 billion liters of water without adversely affecting the harvest. This means a percentage reduction of 34% from the agriculture's water consumption, which in turn would mean that the share of water consumption that went to agriculture would decrease by 9 percentage points. In addition, this would mean a reduction of 25% in total global water consumption, from 4- (Worldometer, 2021) to 3 billion liters. In order for this to be practically possible, knowledge regarding the problems of global water consumption needs to be disseminated. At present, water consumption contributes to the contamination of many groundwater reservoirs as a result of the soil around them becoming porous and leaking saltwater.

Water loss also results in an annual increase of 0.6 mm at sea levels (Lovett, 2012), which currently accounts for 16% of the total annual increase of 3.7 mm/year (Stockholms Stad, 2022). This means that the rise in sea levels theoretically, based on the obtained results, can be reduced by 0.15 mm/year if hydroponics were to reduce global water consumption by 25%. Hence, the rate at which sea levels rise could be reduced by 5% simply by replacing traditional agriculture with hydroponic agriculture. There are major sources of error in a global application of an individual trial with limited resources, but the results nevertheless indicate that hydroponics could be part of the solution to the aforementioned global problems.

The hydroponic cultivation technology is also in line with the global climate goals in terms of animals and nature, as fewer toxins are released into the environment when using hydroponics. This can be clearly illustrated with this project, as the cultivation only required water with a nutrient solution. As a result, nature can be preserved through the increased cultivation of hydroponic crops. From a societal perspective, this is very positive as it is a vital prerequisite to preserving our planetary ecosystems for future generations.

Further development would thus have a positive effect on society as a whole, as it would contribute to more sustainable development. Initially, the expansion of hydroponics would be a cost to society, but with time, normalization, and further research on hydroponic agriculture, several of the global goals set by the UN could be met thanks to this sustainable agricultural technology.

5.2.3 Reasoning for collection- and presentation of data

During this project, measured values were collected daily to obtain as precise results as possible. With the help of these measured values, the results could be reported in detailed tables and graphs to provide an increased understanding of the relationship between the results. All results used summed average values based on all plants in the different crops. This approach was used to obtain further accuracy in the reported results since the margin of error is generally considered to decrease the more data the result is based on. In addition to this, all collections of measured values were carried out with utmost carefulness to obtain as accurate measured values as possible.

When collecting the results, the root systems were excluded from the final results since their weight was difficult to measure. This was because, due to their fragility, it was easy for parts of the roots to tear off when the root systems were rinsed clean from the soil. It was also rather difficult to measure the length of the root systems in the two cultures. As the roots of the traditional cultivation were completely ingrained in the soil and extremely fragile, this made it impossible to produce measured values for the mass on these. Finally, as root systems are not included in the harvest normally consumed by humans, it was considered a logical trade-off to exclude root systems from the final results.

When the results obtained then were applied in a broader societal perspective, more considerations and exclusions needed to be made to provide a more accurate picture of the practical function of hydroponics. As a result, relatively large round-offs were made as it is difficult to practically apply the theoretical values and have them as accurate as they were in the calculations, without having any kind of source of error. These sources of error in this case consist of several different factors. The first of these is that not all agriculture can be conducted hydroponically, as not all plants are suitable for cultivation in a hydroponic culture due to their different needs. The second is that the external factors do not look the same globally, so it will not be possible to minimize evaporation as was possible during this experiment, mainly due to temperature and humidity. The third source of error is that in practice, it will not be possible to have the same light supply as during these experiments. The fourth and probably largest source of error is that this experiment is based on two cultivations that were conducted with only one type of crop, namely Pak Choi. If the cultivation experiments were to be done with a larger range of crops, the accuracy would increase considerably. But, despite this, this study still gives a good indication of how a great reduction in water consumption could be made if all possible agriculture were to transition to hydroponics.

6. List of references

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