People’s Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

UNIVERSITY of TLEMCEN
Faculty of Nature and life Sciences and Earth and Universe Sciences

Department of Agronomy

THESIS

Presented by

MUSENGE Natasha

In order to obtain the

MASTER’S DEGREE

In Plant Production

Theme

Hydroponics: Evaluation of growing lettuce using three different organic nutrient solutions

Supported on 27/06/2023, before the jury composed of:

President	BENDI-DJELLOUL Baha-Eddine	Pr	University of Tlemcen
Supervisor	TEFIANI Choukri	MCA	University of Tlemcen
Examiner	BARKA Fatiha	MCA	University of Tlemcen

Academic year 2022-2023

ACKNOWLEGEMENTS

Above all I thank the Lord all Mighty for the peace I experienced from day one.

I would like to express my sincere gratitude to my supervisor Dr TEFIANI Choukri for taking me in as his student and for all the guidance and support he offered in each step of the way.

My family for the words of encouragement and always cheering me on.

My friends Naomi, Sibeso and Olivia for reminding of how far the Lord has brought me.

My friend Yasmine for being of great help with my studies and making me feel less alone in a place away from home.

The good professors I encountered in my academic years showed outstanding patience with me and I am greatly thankful for that.

DEDICATIONS

To my mum and dad whose wish has always been to see their daughter grow in her academic experiences.

To myself for holding on for this long and the dreams I have based on this particular study.

Summary

Hydroponics is currently standing as a solution to several obstacles faced in traditional farming and the advent of organic hydroponics seems to put the technic in an even higher esteem. The objective of this study was to evaluate the effectiveness of growing lettuce hydroponically using organic nutrient solutions made from animal manure namely: Poultry manure, Cattle manure, and sheep manure. For this purpose, lettuce plants were grown in a simple set up of the kratky method. Plant response to the organic solutions was recorded relating to i) Leaf length and width ii) number of leaves and iii) root length. During the plant development process the measurements mentioned recently were taken every after two days and the solutions were changed once. The EC at the first dilution was set to be in the range between 1200-1240 MS/cm and the pH between the range 5,9-6,1. For the second dilution EC was set to be in the range between 1400-1410 MS/cm and the pH between the range 6-6,1. Temperature of the solutions stayed between 23-25℃.

Results showed that even though there was a slight higher appearance in the length of the lettuce grown in the solution made from sheep manure, there is no significant difference in the productivity of all the manure solutions. It was therefore concluded that organic nutrient solutions made from animal manures used in this particular experiment are all an excellent alternative for producing lettuce organically and avoid/reduce the environmental impact caused by soilless culture, especially in open systems.

Key words: Hydroponics, Nutrient solution, Manure, Kratky method

Résumé

La culture hydroponique est actuellement une solution à plusieurs obstacles rencontrés dans l'agriculture traditionnelle et l'avènement de la culture hydroponique biologique semble mettre la technique dans une estime encore plus grande. L'objectif de cette étude était d'évaluer l'efficacité de la culture hydroponique de la laitue à l'aide de solutions nutritives organiques fabriquées à partir de fumier animal, à savoir : fumier de volaille, fumier de bovins et fumier de mouton. À cette fin, les plants de laitue ont été cultivés dans une configuration simple de la méthode kratky. La réponse des plantes aux solutions organiques a été enregistrée en ce qui concerne i) la longueur et la largeur des feuilles ii) le nombre de feuilles et iii) la longueur des racines. Au cours du processus de développement de l'usine, les mesures mentionnées récemment ont été prises tous les deux jours et les solutions ont été changées une fois. À la première dilution, la CE devait se situer entre 1200 et 1240 MS/cm et le pH entre 5,9 et 6,1. Pour la deuxième dilution, CE a été fixé entre 1400 et 1410 MS/cm et le pH entre 6 et 6,1. La température des solutions est restée entre 23-25°C. Les résultats ont montré que même s'il y avait une légère apparence plus élevée dans la longueur de la laitue cultivée dans la solution fabriquée à partir de fumier de mouton, il n'y a pas de différence significative dans la productivité de toutes les solutions de fumier. Il a donc été conclu que les solutions nutritives organiques fabriquées à partir de fumier animal utilisé dans cette expérience particulière sont toutes une excellente alternative pour produire de la laitue de manière biologique et éviter / réduire l'impact environnemental causé par la culture hors sol, en particulier dans les systèmes ouverts.

Mots clés: Hydroponie, Solution nutritive, Fumier, Méthode Kratky

ملخص

الزراعة المائية حاليا كحل للعديد من العقبات التي تواجهها الزراعة التقليدية ويبدو أن ظهور الزراعة المائية العضوية يضع التقنية في تقدير أعلى .كان الهدف من هذه الدراسة هو تقييم فعالية زراعة الخس في الماء باستخدام محاليل المغذيات العضوية المصنوعة من الروث وهي :روث الدواجن وروث الماشية وروث الأغنام .لهذا الغرض ، نمت نباتات الخس في مجموعة بسيطة من طريقة .kratky تم تسجيل استجابة النبات للمحاليل العضوية المتعلقة ب (i طول الورقة وعرضها (ii عدد الأوراق و (iii طول الجذر .أثناء عملية تطوير المصنع ، تم أخذ القياسات المذكورة مؤخرا كل يومين وتم تغيير المحاليل مرة واحدة .تم تعيين EC عند التخفيف الأول ليكون في النطاق بين 1200-1240 مللي ثانية / سم والرقم الهيدروجيني بين النطاق .5,9-6,1 .بالنسبة للتخفيف الثاني ، تم تعيين EC في النطاق بين MS / cm 1400-1410 والرقم الهيدروجيني بين النطاق .6-6,1 بقيت درجة حرارة المحاليل بين 25-23 درجة مئوية .أظهرت النتائج أنه على الرغم من وجود مظهر أعلى طفيف في طول الخس المزروع في المحلول المصنوع من روث الأغنام ، إلا أنه لا يوجد فرق كبير في إنتاجية جميع محاليل السماد .لذلك تم التوصل إلى أن محاليل المغذيات العضوية المصنوعة من روث الحيوانات المستخدمة في هذه التجربة بالذات هي بديل ممتاز لإنتاج الخس عضويا وتجنب / تقليل التأثير البيئي الناجم عن الزراعة بدون تربة ، خاصة في الأنظمة المفتوحة .الكلمات الدالة : الزراعة المائية ، محلول المغذيات ، السماد ، طريقة كراتكي

SUMMARY

LIST OF ABREVEATIONS

DAT: Day after transplant.

DIY: Do it yourself.

DWC: Deep water culture.

EC: Electrical conductivity.

LED: Light-emitting diode

NFT: Nutrient film technique.

pH: Potential hydrogen.

PVC: Polyvinyl chloride.

LIST OF IMAGES

LIST OF TABLES

GENERAL INTRODUCTION

INTRODUCTION

Lettuce (*Lactuca Sativa)* is a leafy green vegetable belonging to the Asteraceae family and believed to have been first cultivated in ancient Egypt; This plant was cultivated by the Egyptians in order to produce seed oil (**Nafiu et *al*., 2017).** On all continents, lettuce is widely grown, especially in temperate and subtropical areas **(Mou, 2008)**

The hydroponics cultivation technology which is a method of growing plants in the absence of soil and operating with a mineral solution instead, has been taken up by many farmers today because of the serious shortcomings of traditional soil cultivation which includes the existence of ailment causing microbes as well as nematodes, unbefitting reactions of soil, critical compactions of soil, faulty drainage, soil degeneration as a result of erosion etc. **(Sardare & Admane, 2013).**

When it comes to the development in the cultivation of lettuce, hydroponics as compared to the traditional soil cultivation has proven to have an upper hand for reasons such as: The plants harvested are dirt-free and more hygienic, growth of the plants is unfluctuating and planting distance can be in close proximity **(Hopkinson & Harris. 2019).** This opportunity for sustainable agricultural development is practiced by a few countries in Africa as there is little information on African hydroponic practices.

Morgan, 2000a & b and Paul, 2000 as cited by Gül et al. (2002) point out that the demand for goods produced using organic methods has expanded dramatically during the past few years. So, producers of hydroponic systems from many nations began to consider how to use soilless culture to organic farming.

However, there is minimal information on the use of animal manure to create the nutrient solution used in organic hydroponics; particularly the animal manures used in this study (Cattle manure, Poultry manure, and sheep manure).

This study’s first chapter covers the general overview of hydroponics, then followed by the detailed experiment we embarked on to grow lettuce hydroponically in the second chapter, the final chapter is based on the results obtained from the experiment as well as comments on the results, challenges we encountered, recommendations and a conclusion of the matter at hand.

HYDROPONICS OVERVIEW

1. What is hydroponics?

Hydroponics is a soil-less culture technique that is based on the cultivation of plants using a mineral nutrient solution (**Maharana & Koul, 2011**). A deeper definition by **Fussy & Papenbrock, (2022)** states that the term "hydroponics" refers to soilless culture systems with inert substrates or without any aggregates, where plants are grown with their roots reaching into an aerated nutrient solution that may be either flowing or static.

1.1 Why opt for hydroponics?

Baras, (2018) rose a question that since hydroponics is practically reanimating or remaking the same conditions found in soil, why not just stick to using soil for cultivation of plants? In the sense that; like soil with its physical structure, hydroponics offers a firm grip to the plant roots through the aid of the artificial media mentioned above as well as trellis structures. He goes on stating how the crucial nutrients found in soil to be provided for the plant can also be made available in a hydroponic system using alternative ways; these water-soluble nutrients are extracted from both organic and inorganic origins. Lastly he states that just as soil gives shelter to important microbial inhabitants which build a positive association with the plant roots, the nature of hydroponic systems also provide conditions for these microbes to reside and flourish. To which he respond with the following 16 advantages of hydroponics:

1.1.1 Does not require quality soil

Traditional soil cultivation calls for the use of good quality soils which has its own number of limitations when the quality of the soil is affected by its degradation or deterioration hence reducing the soil’s most important roles (**Constanza et al. 1992a, b, Bastida et al. 2006**). On the other hand soilless cultivation eliminates the much needed effort to create or maintain good quality soil.

1.1.2. Prospects for faster plant growth

Hydroponics allows the roots of the plant to swim in a rich nutrient solution with stable access to water and oxygen leading to plants growing at a much faster rate as compared to the growth rate in soil which is affected by a number of hindrances which affect the roots’ ability to access the nutrients, such as: the inconsistent distribution of the nutrients as well as the nutrients being extremely attached to soil particles, the slow rate at which microbes may break-down the nutrients from its fount into a form the roots can easily access, insufficient water or excessive water**(Baras, 2018)**

1.1.3. Less space is needed.

Soilless cultivation removes the need for roots to grow and expand in search for the nutrients spread around in various areas of the soil because the nutrients are readily available in a much closer proximity. Spacing of the plants is only restricted by the canopy of the plants **(Baras, 2018).**

1.1.4. Minimal restrictions on the growing season.

With the aid of heaters, chillers, or simple practices like burying a hydroponic reservoir, we are able to regulate and adjust the temperature at the root zone during different seasons, this is because the temperature of the roots affect the plant more than that of the leaves **(Baras, 2018)**

1.1.5. Friendly to diverse locations

Hydroponics offers an opportunity for plant growers to grow plants even in areas that are normally considered unfavorable for plant cultivation. Areas with poor soil quality, harsh climate and limited water accessibility such as deserts; Deserts if not for the insufficient water (which is a problem that is taken care if hydroponics is welcomed), are a good place to cultivate plants because of their proper exposure to light and contain less pests **(Baras, 2018)**.

1.1.6. Utilizes less water

Soil is prone to the loss of water through the process of evaporation as well as drainage. In hydroponics, evaporation is tackled by placing a covering over the water reservoir while drainage is taken care of in the sense that the water being drained is accumulated to be put to use again. We use less water because any irrigation water not taken up by the plant directly can be reutilized **(Baras, 2018)**.

1.1.7. Zero weeding and herbicides

This benefit of hydroponics helps plant to save both time and money which may be used in other needed areas. Moreover, crop damage which is likely to occur due to careless placement of the herbicides resulting in them being accidentally blown into the garden **(Baras, 2018)**.

1.1.8. Lessens or removes the need for pesticides.

Even though outdoors and greenhouse hydroponic gardens are normally not pest free as compare to indoors, Hydroponics still is outstanding when it comes to reducing any pest concerns. Pests find it easier to hide in soil and fallen decaying plant parts such as leaves nut there is no room for this in a hydroponic garden **(Baras, 2018)**.

1.1.9. Reduces or eliminate agricultural runoffs.

Traditional soil gardens suffer from the consequences of runoffs which may happen because of a sudden windstorm or rainstorm right after the application of fertilizers or the fertilizers may be swept away even by regular irrigation. The advent of advanced techniques in hydroponics put an end to this foe by including in the whole plant production process: advanced water testing, chemistry, as well as an exceptional knowledge of the plant's particular nutrient needs **(Baras, 2018)**. Moreover, we normally flush or dump out the nutrient solution in hydroponic systems after a couple of weeks to circumvent any sort of mess amongst the nutrients due to a contrast in nutrients. Plants take in nutrients at different rates and so some nutrients may be present in excess or too little amounts compared to what the plant actually needs but these recurring flushes make it possible for the plant to be provided with its needed nutrients in a well-balanced proportion. The drained wastewater may even be used in outdoor gardens or potted plants **(Baras, 2018)**.

1.1.10. Aptness to control the nutrient content

Some misleading conceptions say that foods produced in hydroponics carry a less nutrient content as compared to those grown in traditional soil farms to which many studies over the years have shown that the results are evenly mixed **(Baras, 2018)**.

For example, lettuce grown hydroponically in Japan by the Oizumi Yasaikobo Co., Ltd., in Chichibu City, is grown specifically for clients suffering and battling kidney disease and undergoing the dialysis treatment, they are urged to not eat vegetables with high potassium content and hydroponics makes it possible for this farm to grow low potassium lettuce **(Baras, 2018)**.

1.1.11. Increased ability to direct crop growth for specific characteristics

Characteristics or plant features like the size of the leaf, leaf color, size of roots and plant height can be altered and manipulated **(Baras, 2018)**.

1.1.12. Clean and minimal mess

Hydroponic gardening is not messy and muddy compared to the traditional farming. This means the plants grown hydroponically do not call for much washing and rinsing compared to traditionally grown plants **(Baras, 2018)**.

1.1.13. Easier and demand less work compared to soil.

Hydroponics may seem complicated at first glance but its way easier compared to growing crops in soil; No need to extract weed because they're non-existent, fertilization is made easier and it's also easy to automate **(Baras, 2018)**.

1.1.14. Easy to master and replicate results.

Experience is said to be the best teacher; hydroponics offers this luxury because crops grow at a faster rate, creating an opportunity for the growers to gain more experience in a shorter time period. Hydroponics also empowers the growers to replicate the exact nutrients available and irrigation frequency **(Baras, 2018)**.

1.1.15. Expands the potential to handle soil-borne pathogens

Root rots and bacterial wilts are difficult to have under control in traditional gardens, hydroponic gardens however have a way of eradicating such pathogens by simply cleaning up the hydroponic system if any problem arises which is rare **(Baras, 2018)**.

1.1.16. Minimizes the potential of contaminating crops.

Harmful pathogens like E. coli, Listeria, and Salmonella are mostly spread into the soil by the use of animal manures that have not been prepared in a hygienic manner or with proper attention. Soil can also be contaminated by the presence of heavy metals in the soil or in irrigation systems **(Baras, 2018)**.

2 Hydroponics challenges

These sixteen advantages and more that keep coming up as the years go by are proof that hydroponics is the key to sustainable agriculture worldwide. Nevertheless, here are a few more advantages alongside a couple of disadvantages that also need to be considered and hopefully dealt with in future researches **(Baras, 2018).**

Table 1: Advantages and disadvantages of hydroponics (Rosario Di Lorenzo et al., 2013)

ADVANTAGES	DISADVANTAGES
Grow on poor soil	High investment and energy costs
No need for soil sterilization	Environmental problems (disposal of exhausted substrates such as rockwool, loses in the soil of draining nutrient solution, use of huge amounts of plastics)
No risk of accumulation of phytochemical residue (bromine residues, etc.), also in the groundwater	Absence of suitable cultivars
No need for tillage, manuring, initial fertilization	No indications for the distribution of pesticides with the nutrient solution
Elimination or reduction of attack from soil-borne pathogens	No hydric, thermal, nutrient and biological flywheel of the substrate
No herbicide treatment	Risk of epidemics
Rapid rotations no longer needed	Occurrence of diseases normally absent in soil
Greater water use efficiency	Highly professional operator skills needed
Better use of fertilizers (efficient use of nutrients)	Dependence on electricity and other economic sectors
Greater uniformity and earliness	Continuous monitoring
Increase in yield (better plant health, great plant density, more productive longevity)	
Better overall production quality	
More efficient greenhouse management (rapid succession, high greenhouse efficiency, vertical exploitation)	

3. History of hydroponics

As stated by **Caputo (2022)**, hydroponics as a technology and term may be recent but the concept of growing plants using water as a medium is something that has been around for a very long time.

Waiba et al. (2020) shed more light on the history of hydroponics by expressing that even though there is no proper recording on ancient soilless cultivation, we however get to see it unravel in Sir Francis Bacon's book, Sylva Sylvarum published in 1627 where he records the cultivation of terrestrial plants in the absence of soil and nominated it as “water culture”; followed by the 1666 experiment led by Robert Boyle based on growing vegetables and plants with their roots swimming/submerged in the water; water culture experiments with pear mints led by John Woodward in 1699 where he also discovered that plants and vegetables grow better in less pure water as compared to distilled water; experiments conducted in 1842 and 1895 by Julius von Sachs and Wilhelm Knop respectively led to the first perfection of mineral nutrient solutions used in soilless cultivation, this was carried out by the German botanist in 1860; Gericke in 1937 proposed the term “hydroponics” to refer to the cultivation of crops with their roots in contact with nutrient solution; in 1938 two plant nutritionists Dennis R. Hoagland and Daniel I. Arnon developed a nutrient solution known as Hoagland solution and is still used in hydroponics till date. During the course of the 1980’s, automated hydroponics and computer farms mainly for commercial hydroponics were established worldwide **(Goswami and Yadav, 2022)**

4. Future scope

On future hydroponic speculations and researches, **Waiba et al. (2020)** go on stating that with the world’s rapidly growing population we will eventually run out of large cultivation lands, to which hydroponics is an additional source for plant and vegetable cultivation. NASA has also taken keen interest in this hydroponics technology with their intensive studies on the matter, which will help with the production of plants in space benefiting the Moon or long-term colonization of Mars; hydroponics is the way to go for this plan as it is very difficult to transport cultivation soil into space.

5. Classification of hydroponics

According to **Shrestha and Dunn (2017)** of the Oklahoma state university, hydroponic systems can be classified into two growing systems: liquid and aggregate. Plant roots cannot be supported by a solid media in liquid systems, but they can be supported in aggregate systems. In addition, hydroponic systems can further be classified as: closed (extra solution is recovered, replenished, and recycled) and open (after the nutritional solution is provided to the plant roots, it is not reused).

Nalwade and Mote, (2017) however, classify hydroponic systems into three by classing aeroponics independent from liquid hydroponics as illustrated in the image below:

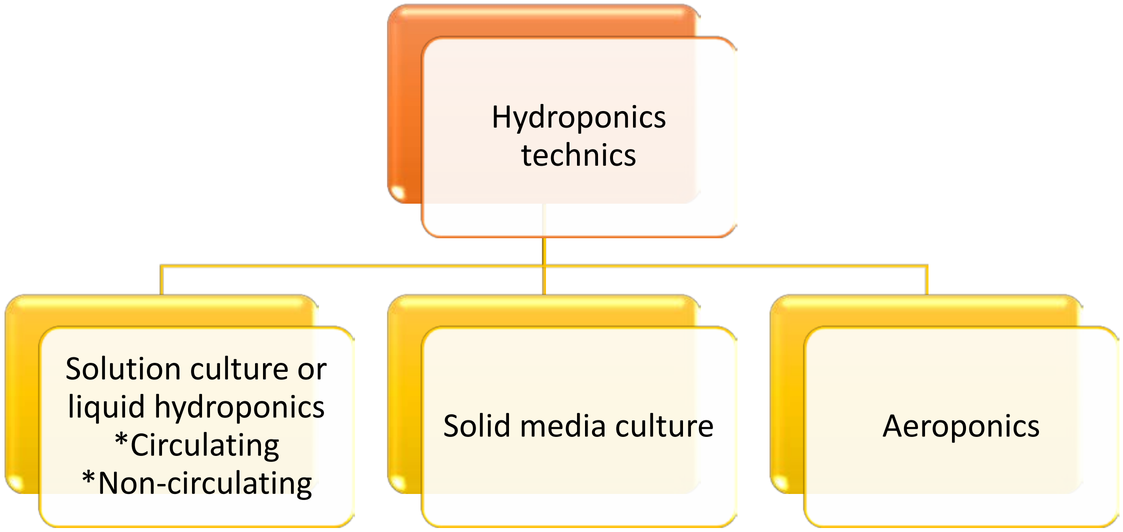

Image 1: Classification of hydroponics (Nalwade and Mote, 2017)

5.1. Solution culture or liquid hydroponics

5.1.1 Circulating method (Closed system)

a) Nutrient film technique (NFT)

The nutrient film technique uses a recirculated design to continually spray highly oxygenated dissolved nutrients over the roots of plants. Plants are commonly grown in baskets suspended in PVC pipes. Through irrigators at the top of each sloping pipe, the solution is fed from a holding tank, and the runoff from the bottom of the channels is pumped back into the tank. The nutrition solution is subsequently continually recycled **(El-Kazzaz & El-Kazzaz, 2017)**. It is feasible to reduce the pipe's angle and include an overflow pipe, much like in an off-and-flow system. In the event of a power outage or pump failure, this would act as a reserve of nutrients. The nutrient film approach is especially well suited to plants with small root balls like lettuce, strawberries, and herbs because of the constrained space of a PVC pipe and the need for nutrients to continuously flow over the roots **(El-Kazzaz & El-Kazzaz, 2017)** .

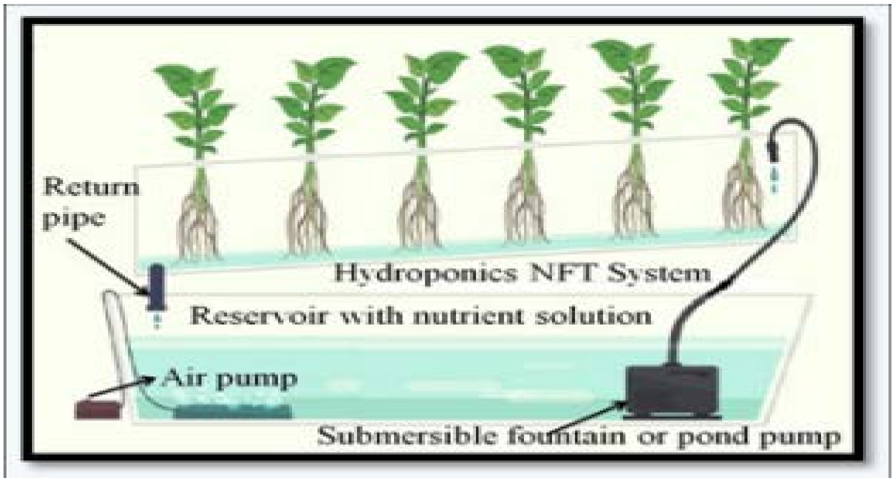

Image 2: NFT System (El-Kazzaz & El-Kazzaz, 2017)

b) Water culture or deep water culture (DWC)

In this kind of hydroponics, plants are suspended on float platforms on a bath of nutrient medium, which is supplied with oxygen via an air pump that continuously circulates to the crop's root zone. It is simple to set up in fish ponds, concrete basins, glass basins, ice boxes, plastic containers, and containers covered with polypropylene sheets **(Islam et *al*., 1980 as cited by Waiba et *al*., 2020)**.Since the plants in this system are in floating contact with the nutrient solution, there is little chance that a power loss will harm them or even halt the air pump. The most often grown vegetables in this system include lettuce, Chinese cabbage, spinach, etc **(Waiba et *al*. 2020).**

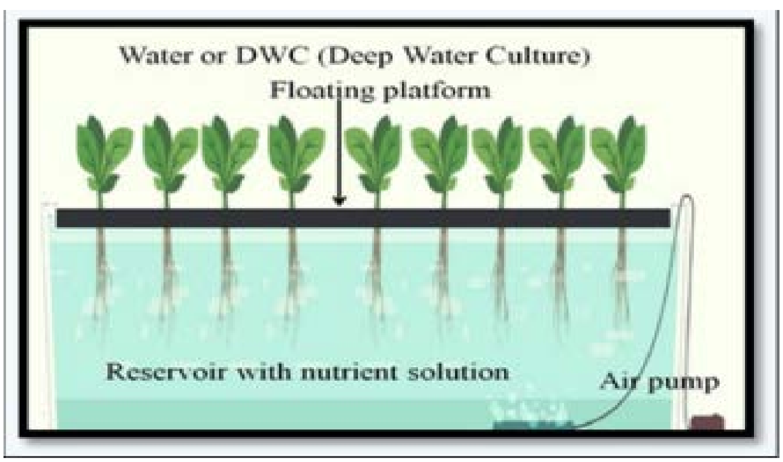

Image 3: DWC System (El-Kazzaz & El-Kazzaz, 2017)

c) Wick System

Of all hydroponic system kinds, it is the most basic because it generally lacks all moving parts, power, and water circulation pumps. In areas without access to power, it may be advantageous. However, the wick serves as the link between the nutrient solution and the potted plant, aiding in the circulation of the nutrient solution to the crop root zone **(Waiba et al. 2020).**

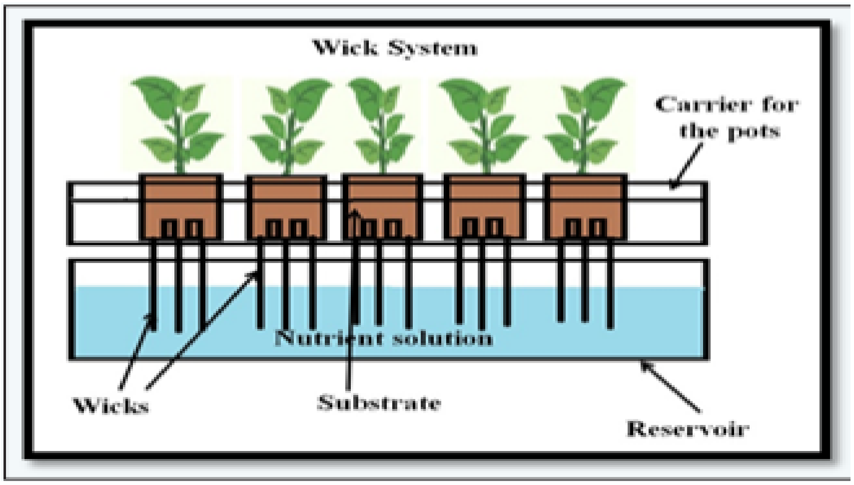

Image 4: Wick System (El-Kazzaz, & El-Kazzaz, 2017)

d) Ebb and Flow Method

This method closely resembles the drip irrigation system because it similarly uses two containers, one at the top for crops and one at the bottom for fertilizer solution. Using a water pump, the nutritional solution is delivered through drippers at the stem of each plant and into the top container, where the crop is growing **(Pradhan & Deo, 2019 as cited by Waiba et *al*., 2020).** The extra water is being cycled back to the bottom container. In order to properly flood the grow tray, the pump is turned on for 30 minutes and then turned off for 15 minutes. If the pump is turned off, all nutrients are removed from the crop growth tray through the pump line. The vacant phase enables for oxygen flow to the crop's roots zone, hence these systems do not need air stones. Nearly all vegetables can thrive in drip systems, which are also suitable for crops with big root balls **(Waiba et *al*., 2020).**

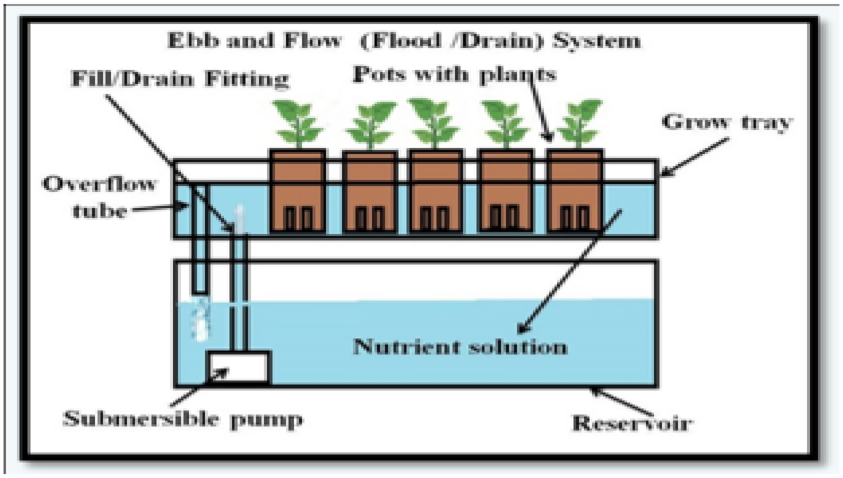

Image 5: Ebb and Flow System (El-Kazzaz & El-Kazzaz, 2017)

5.1.2 Non-Circulating Methods (open systems)

a) Root dipping technique

With this method, plants are cultivated in tiny pots that are only partially filled with growing medium. The pots are positioned so that their lower 2-3 cm are immersed in the nutritional solution. For nutrient and air absorption, a few roots are suspended in the solution while others are dipped in it. This low-tech growth technique is simple to set up and requires little upkeep. Importantly, this method doesn't need pricey equipment like electricity, a water pump, channels, etc. **(Goswami and Yadav, 2022)**

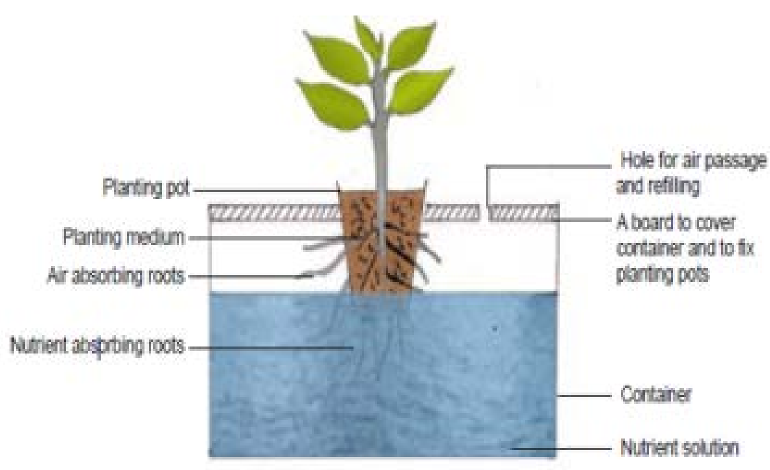

Image 6: Root dipping technique (Mariyappillai et al., 2020)

b) Floating Technique

This approach involves placing plants in small pots, fixing them to a Styrofoam sheet or other light plate, and allowing them to float atop a nutritional solution that has been placed into the shallow (10 cm deep) container. The solution is then artificially aerated **(Goswami and Yadav, 2022).**

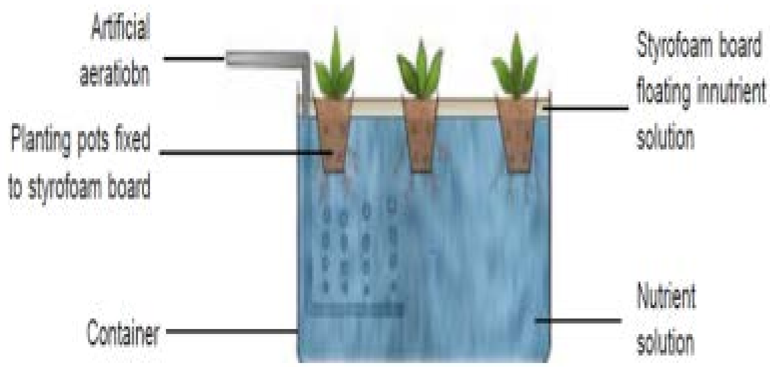

Image 7: Floating Technique (Mariyappillai et al., 2020)

c) Capillary action technique

Different sized and shaped planters with holes on the bottom are utilized. Seedlings or seeds are sown in the inert medium that has been poured into the pots. These pots are set in low containers that are fertilizer solution-filled. Capillary action carries nutrient solution to inert media. In this method, aeration is crucial hence consequently, used old coir dust combined with sand or gravel can be utilized. Use this method for indoor, flowering, and ornamental plants **(Goswami and Yadav, 2022).**

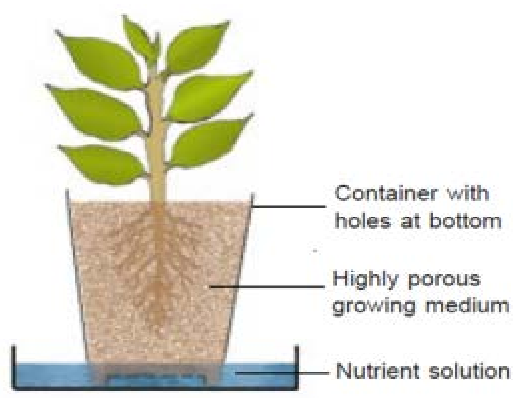

Image 8: Capillary action technique (Mariyappillai et al., 2020)

d) Suspended net pot (Kratky method)

This experiment was carried out using this technique. **Kratky, (2003)** declares this method as a special and effective way for growing vegetables because the entire crop may be grown with just a single application of water and nutrients. It is executed in a perforated container that is supported by a fixed cover over a tank, plants are grown in a minimal amount of substrate. Initially, the lower part of the container is submerged in nutrient solution. The substrate is then automatically wetted by capillaries to irrigate the young plant. As the plants develop, the level of the fertilizer fluid falls below the container. The substrate can no longer be directly wetted by capillaries at this point, but the newly forming roots are still quite capable of absorbing the nourishing solution.

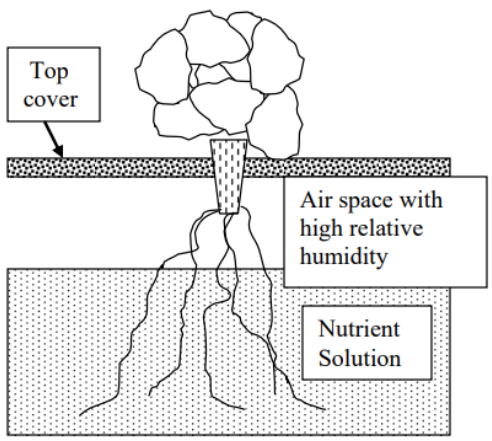

Image 9: Kratky method (Kratky, 2003)

5.2 Solid media culture or aggregate system

The inert medium employed, such as sand, gravel, or rock wool, is what gives the media culture method its name. It uses a solid medium for the roots. There are two fundamental variations for each medium: sub-irrigation and top-irrigation **(Misra and Ghosh, 2021)**. According to **Goswami and Yadav (2022)**, this system is further categorized into the following four techniques.

a) Hanging bag technique (Open system)

Tüzel et *al*., (2019) explains this system as one in which we utilize plastic bags stuffed with loose grains or porous slabs. These bags can be made and purchased ready to use or they can be filled by the grower. Perlite is the most widely utilized granular substance in

Mediterranean nations. For the purpose of collecting the drainage solution, bags are inserted into panels or channels. They have holes made for planting on top of them; the number of planting holes varies depending on the crop. Later on, a dripper is inserted in each one, and nutrient solution is poured into the substrate until it is completely saturated. For 24 to 48 hours, saturation is kept in place to give the substrate time to absorb the solution. The base of the plastic envelope is then sliced or punctured with tiny holes to allow the surplus nutritional solution to drain. After transplanting the plants, a dripper is put next to each one. Less frequently, the bags are positioned vertically with their tops open for growing a single plant. These have the drawbacks of being more difficult to move, requiring more water, and maintaining uneven moisture levels **(Tüzel et *al*., 2019)**

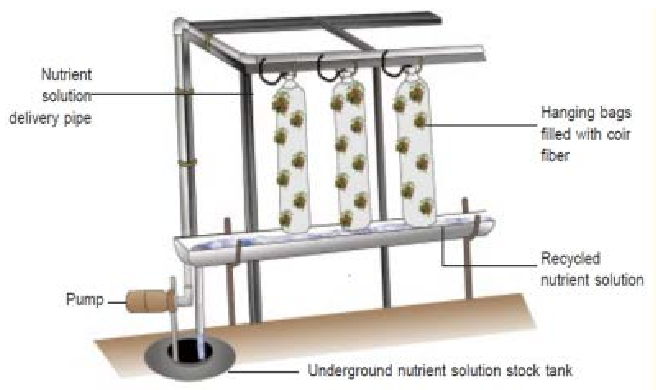

Image 10: Hanging bag technique (Mariyappillai et al., 2020)

b) Grow bag technique

In this method, 1 to 1.5 m long white (inside black) UV resistant polythene bags are utilized, which are filled with used, sterile coir dust. These bags measure around 18 cm in width and 6 cm in height. On the floor, these bags are arranged in rows, end to end, with space between them for walking. Depending on the type of crop being grown, the bags may be arranged in paired rows. On the top surface of the bags, tiny holes are drilled through which seedlings or other planting materials in net pots are forced into the coir dust. Per bag, 1-2 plants can be planted **(Goswami & Yadav, 2022).** On each side of the bags, there are two tiny drainage or leaching slots. Each plant receives fertilizer through a black capillary tube connected to the main supply line. Before putting the bags down, the floor is completely wrapped in white UV-resistant polythene. The plants receive reflected sunlight from this white polythene. Additionally, it lowers the frequency of fungi illnesses and the relative humidity between plants **(Goswami & Yadav, 2022).**

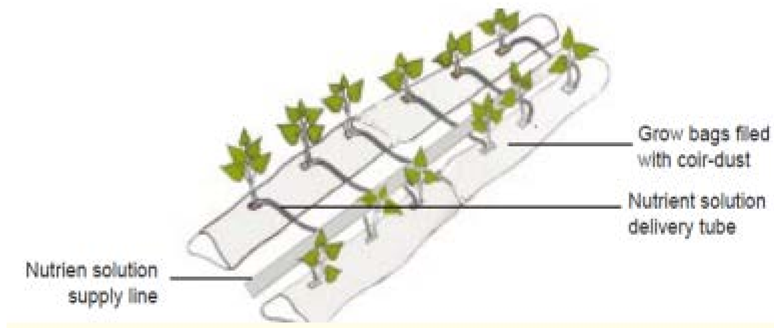

Image 11: Grow bag technique (Mariyappillai et al., 2020)

c) Trench or trough technique

In this open technique, plants are raised in above-ground troughs made of bricks or concrete blocks or in small trenches dug into the earth. To keep the growing media isolated from the surrounding earth, both trenches and troughs are lined with waterproof material (thick, double-layered polythene sheets resistant to UV rays). Depending on how simple it will be to operate, the width of the trench or trough can be chosen. It is possible to grow two rows of plants in wider trenches or troughs **(Goswami & Yadav, 2022).** Depending on the plants to be grown, a depth of at least 30 cm may be required. The media for this culture can be made of peat, vermiculite, perlite, old sawdust, sand, gravel, old coir dust, or a combination of these elements. A drip irrigation system or hand application of water and nutrients are also options, depending on labor availability. To drain out extra nutritional solution, a well-perforated pipe with a 2.5 cm diameter can be inserted at the bottom of the trough or trench. To support the weight of the fruits, tall growing vine plants (such as cucumber, tomato, etc.) need additional support **(Goswami & Yadav, 2022).**

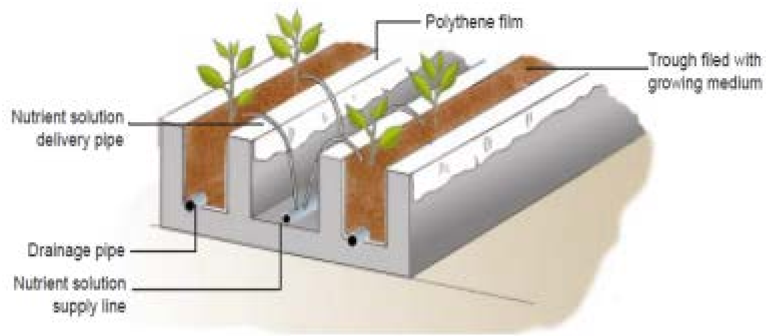

Image 12: Trench or trough technique (Mariyappillai et al., 2020)

d) Pot technique

Similar to trench or trough culture, the pot technique uses clay or plastic pots filled with growing medium. The size of the container and the growing medium are determined by the needs of the crop. Typically, the capacity falls between 1 and 10 liters. Similar to a trough or trench culture, growing medium, nutritional solution supply, providing support for plants, etc. are all involved **(Goswami & Yadav, 2022).**

Image 13: Pot technique (Sardare & Admane, 2013

6. Aeroponics

This technique involves feeding a nutrient solution of misted water while enclosing the root system in a dark space **(Gopinath et al., 2017).** The roots are at saturation humidity and in darkness (to prevent algae growth). Periodically, a misting mechanism mists the roots with the nourishing solution. The mechanism typically only activates for a brief period every 2.3 minutes. This is enough to maintain moisture in the roots and the aerated nutrition solution.

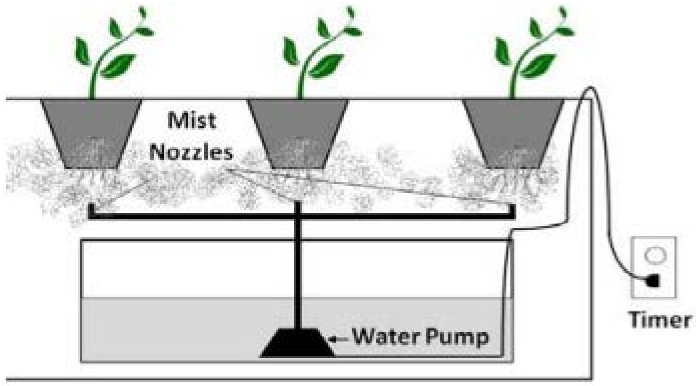

Image 14: Aeroponic system (Gopinath et al., 2017)

7. Nutrient Solution

Nguyen et al. (2021) as cited by **Ali Al Meselmani (2023)** elaborates that the majority of the plant nutrients utilized in hydroponics are inorganic and ionic forms that are dissolved in water and that establishing a nutrient solution that delivers a desirable ratio of ions for plant growth and development is regarded as a crucial step in cultivating crops in hydroponic systems since all the necessary ingredients for plant growth are supplied using various chemical combinations.

A soilless system, if designed properly, will provide the plants with optimal quantities of all their vital elements, in contrast to growing plants in soil, which provides nutrients to the plants but may not always in the right amounts **(Resh, 2016)**.

Currently, 17 elements—including carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese, molybdenum, boron, chlorine, and nickel—are considered essential for most plants **(Salisbury & Ross, 1994 as cited by Trejo-Téllez and Gómez-Merino,2012)**.

Citing **Trejo-Téllez et al.(2007)**, **Trejo-Téllez & Gómez-Merino(2012)** goes on to state that Other substances, including sodium, silicon, vanadium, selenium, cobalt, aluminum, and iodine, among others, are regarded as advantageous because some of them can promote growth, make up for the toxic effects of other substances, or possibly take the place of necessary nutrients in a less specific capacity.

7.1. pH and EC

Trejo-Tellez and Gomez, (2012) elaborates that a numerical scale called pH (hydrogen ion concentration) is used to describe how acidic or basic an aqueous solution is. On a scale of 1 to 14, with 7 representing neutrality, pH is measured. In hydroponics cultivation, pH of the nutrient solution is crucial. Plants lose their capacity to absorb some of the vital nutrients needed for healthy growth when the pH is off-balance. There is a specific pH level for all plants that will yield the best outcomes. While each plant will have a different preference for this pH level, most plants generally prefer a slightly acidic growing environment between 5.5 and 6.5. The solution must dissolve the nutrients. Your plant can no longer absorb nutrients once they have precipitated out of the solution; if this is not fixed, it will experience deficiencies and eventually die. When the pH drops as well, some nutrients will precipitate out of the solution **(Trejo-Tellez and Gomez, 2012)**.

Gaikwad & Maitra, (2020) describes and explains EC sa way to gauge the amount of nutrients in a solution. The amount of dissolved solids in a solution increases with conductivity. Poor nutrient concentration is implied by poor conductivity, which typically causes nutrient deficits and delayed plant growth. However, extremely high levels might cause the plants to burn or die. If conductivity is too high, delicate plant cuttings and seedlings may burn. Once the plant starts to grow, it needs a strong nutrition solution so that concentrated nutrients may be added to raise conductivity. While some plants prefer nutrient concentrations that are softer, others produce fruits of higher quality and concentration (**Gaikwad & Maitra, 2020)**

7.2 Temperature

Plants are impacted by temperature in two ways. The tendency of a plant to develop more quickly tends to increase the plant's need for water. High temperatures also cause plants to use more water to evaporate in order to cool themselves **(Bhattacharya, 2017)**.

8. Light

A hydroponic garden cultivated in an enclosed space will require more hydroponic lighting than an area that receives natural sunshine. Keep in mind that sunlight is less reliable than artificial lighting, so whenever the amount of available light starts to decline, prepare to supplement the sun with hydroponic lights **(Bhattacharya, 2017)**.

MATERIALS AND METHODS

1. Location

This practical experiment was carried out in an office on the fourth floor of Abou Bekr Belkaid University.

2. Materials used

a) 5L plastic container: Used for germination of seeds.

b) 8L plastic containers: Used as storage for concentrated nutrient stock both before and after filtration and sterilisation of the stock.

c) 8,5L plastic bowls: Used to hold nutrient solution and grow lettuce therein.

d) Tape: To seal up the 8L containers after being cut.

e) Box cutter: Used for all the cuttings involved in experiments.

f) Cloth: Used as a filter material.

g) Bunsen burner: Heat source for easy cutting of lids.

h) Catering pan: Used in the sterilization process.

i) Gas stove: Used to boil the fermented stock in order to sterilize them.

j) Plastic cups: To contain the seedlings.

k) Trash bags: Used to shield bowls from the sun.

l) Electrical conductor/EC probe: Used to measure the EC of the nutrient solutions.

j) pH meter: Used to measure the pH of the solutions.

k) Sponge: Acts as plant support in the cups.

l) Bucket: Used for dilution of concentrated nutrient solution.

j) Soldering gun: Used to make holes in the cups.

3. METHODE

3.1. Germination

Lettuce seeds were sown for germination on the 17th may, 2023. A 6L bottle was cut open and filled with fertile soil for this process.

Image 15: Two weeks old lettuce seedlings (original photo)

3.2. Preparation of the system

3.2.1. Plastic bowls

Five holes were made in each lid. The holes having the diameter of 6cm so they can hold cups having a diameter of 7cm. These holes were cut using a box cutter and some heat from a Bunsen burner to make the cutting easier.

Image 16: Illustration of bowl preparation (original photo)

3.2.3. Disposable cups

A total of 20 disposable cups were used. We made openings on the sides and at the bottom of each cup using a soldering gun.

Image 17: preparation of culture cups (original photo)

3.2.3. Sponges

Sponges were cut into small rectangular pieces, enough to fit at the bottom of the disposable cups.

Image 18: cutting of sponge into rectangular pieces (original photo)

4. Nutrient solution

The nutrient solution was made using three different organic manures: Poultry manure, goat manure, and cow manure. The following are the steps we took to create the final nutrient solution; the same steps apply to all three manures.

4.1 Fermentation

We placed the manures in three different eight litre (8L) bottles. Using a box cutter, these bottles first had to be cut open on the top to widen the open area for easy entrance of the manures. Two and a half buckets of water were added to each bottle and mixed using a metal rod. The bottles were labelled with their specific content and sealed back on the top where they were opened then left in a room to ferment for three days. During the three days of fermentation, the bottles were shaken once a day to mix up the solutions more.

Image 19: Illustration of fermentation process (original photo)

4.2. Filtration

After three days of fermentation, it was time to filter the solutions in order to extract a residue-free solution. A DIY filter material made from the cutting of the top of an eight litre bottle with a clean cloth/rug tied on the area where the bottle's lid is normally placed. A metal rod was used to steer and scratch the bottom of the filter to speed up the process of filtration.

Image 20: Filtration process/ residue after filtration (original photo)

4.3 Sterilization

It is important to sterilize the filtered liquids to kill any harmful pathogens, bacteria, or parasites that may be present. This can be done by using a sterilizing agent such as hydrogen peroxide or in our case by heating the liquid. The liquid was heated on a gas stove at its highest temperature; once the liquid came to boiling, a timer of 15 minutes was set. After the 15 minutes depleted, the liquids were put back in their containers (already rinsed), after they cooled down.

Image 21: Manure solution being sterilised by heating (original photo)

4.4 Dilution (EC and pH adjustments)

For the dilution process we cut open a 1.5L bottle to fill a bucket with tap water; the bottle was filled five times. The tap water's EC was measured first. The concentrated manure water (nutrient solution) was then added to the water gradually until desired EC. The pH was adjusted either using sulphuric acid to lower it or sodium hydroxide to elevate it until it stays in required range. For each concentrated manure water (nutrient solution) the same process was repeated. The final nutrient solutions were poured into the 8,5L bowls, filling the bowls up until the liquid touches the bottom of the cups.

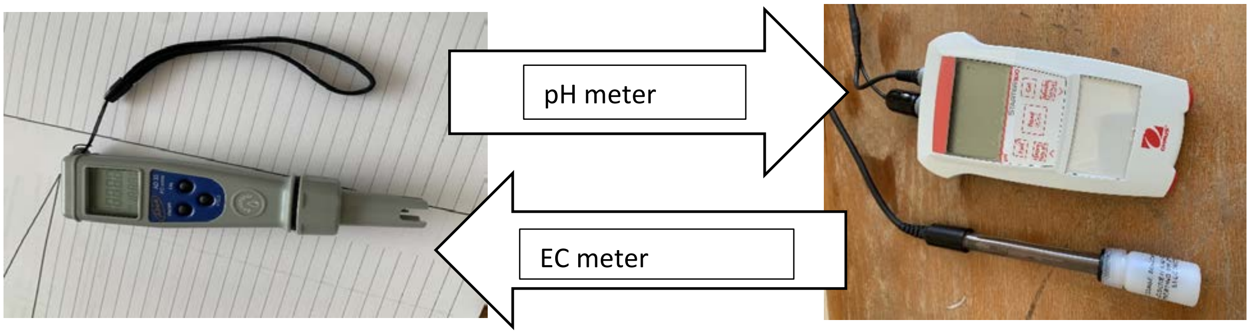

Image 22: Apparatus used to measure EC and pH (original photo)

Image 23: Illustration of EC being measure and placement of the cups (original photo)

Note: In this experiment, the nutrient solution was changed once and the bowls were cleaned with only tap water. Initial EC and pH were recorded and later on we adjusted the both EC and pH according to plant's growth stage.

5. Transplanting and seedling selection

The soil holding the seedlings was watered a few hours before uprooting the seedlings in order to moisturize and soften the soil around the root area/zone. The seedlings were uprooted using bare hands for proper root care. 20 seedlings were selected based on uniform phenotypic traits. These seedlings were further on handled with care while thoroughly washing off the dirt from the roots. They were later on transplanted into the systems prepared beforehand.

Image 24: Uprooted seedlings before and after washing the dirt from roots (original photo)

6. Final hydroponic system look

The bowls, without their lids were placed inside black trash bags and then the lids were later on placed on top of the bowls in order to seal them. After cutting in cross form the plastic area right beneath the holes on the lids, the disposable cups were then placed in the holes. Prior to the cups being placed in, the sponge cubes were placed at the bottom of the cups as well as the seedlings (having their roots sipping through the hole at the bottom of the cup).

Image 25: Final system (original photo)

7. Cultivation/Growing environment (Sunlight)

It is basic knowledge that sunlight is needed for photosynthesis and so the bowls were placed near the window for proper light exposure and gaseous exchange as well.

Image 26: Area of cultivation (original photo)

Note: The placement of the four culture bowls was being interchanged every time measurements were taken in order for all the plants to get equal sunlight exposure.

RESULTS AND DISCUSSION

1.Plant growth parameters

The evaluated growth parameters: leaf length, leaf width, root length, number of leaves were recorded and it was found that the days after transplanting (DAT) factor had great significance. The results showed that different organic nutrient solutions made from animal manure had no significant difference on the plant growth parameters as compared to that grown only in tap water.

1.1. Number of leaves

In image 23 we see leaves right after transplanting (poultry, sheep and cattle manure solutions); with each plant having maximum of 3 leaves.

Image 27: appearance of leaves on day of transplant (original photo)

Each solution seemed to perform well in a week's time as there was appearances of at least two new leaves.

A. The following pictures were taken 7 days after transplant:

a) Cattle manure solution

b)Poultry manure solution

b) Sheep manure solution

Image 28: appearance of leaves 7 days after transplant

The results indicate that there was a difference from DAT

The tap water was inevitably picking up quite slowly compared to the three manure solution.

d)Tap water culture

B. The following visual results were taken 14 days after transplant:

a) Cattle manure solution

b) Poultry manure solution

Image 29: appearance of leaves 14 days after transplant (Cattle manure solution, Poultry manure solution)

c) Sheep manure solution

d) Tap water culture

Image 30: appearance of leaves 14 days after transplant Sheep (manure solution, Tap water culture)

1.2. Root length

a) Cattle manure solution

7 days after transplanting (4,5cm)

14 days after transplanting (6,5)

Image 31: appearance of leaves 7 days after transplant

b) Poultry manure solution

7 days after transplanting (4cm)

14 days after day of transplanting (5,5cm)

c) Sheep manure solution

7 days after transplanting (6,6cm)

14 days after transplanting (8,5cm)

Image 32: Root length 7 days after transplant and 14 days after transplant (Sheep manure solution)

d)Tap water culture

7 days after transplanting (9,3cm)

14 days after transplanting (10,4cm)

Image 33: Root length 7 days after transplant and 14 days after transplant (Tap water culture)

1.3. Leaf length and width

Same mode used to measure root length was used to measure leaf length and width

Image 34: Illustration of leaf length and width measurement.

For leaf length we recorded 7 days after transplanting: 8,2cm (cattle manure), 8,4cm (sheep manure), 9,4cm (poultry manure), 8cm (tap water) and then later on 14 days after transplanting: 10,5cm (cattle manure), 11,5cm (sheep manure), 11cm (poultry manure), 8,5cm (tap water)

For the width we recorded 7 days after transplanting: 3cm (cattle manure), 3,4cm (sheep manure), 3,3cm (poultry manure), 2,5cm (tap water) and then later on 14 days after transplanting: 4,3cm (cattle manure), 4,5cm (sheep manure), 4,5cm (poultry manure), 3,9cm (tap water)

2. Physiological disorders

The physiological disorders our plants suffered from (brown stain, root rot) were believed to have been a result of poor seedling selection or improper distribution of nutrients in the solutions.

Image 35: Brown stain

Image 36: root rot

However the worst was wilting due to high temperatures

Image 37: Wilting leaves.

1. EC and pH

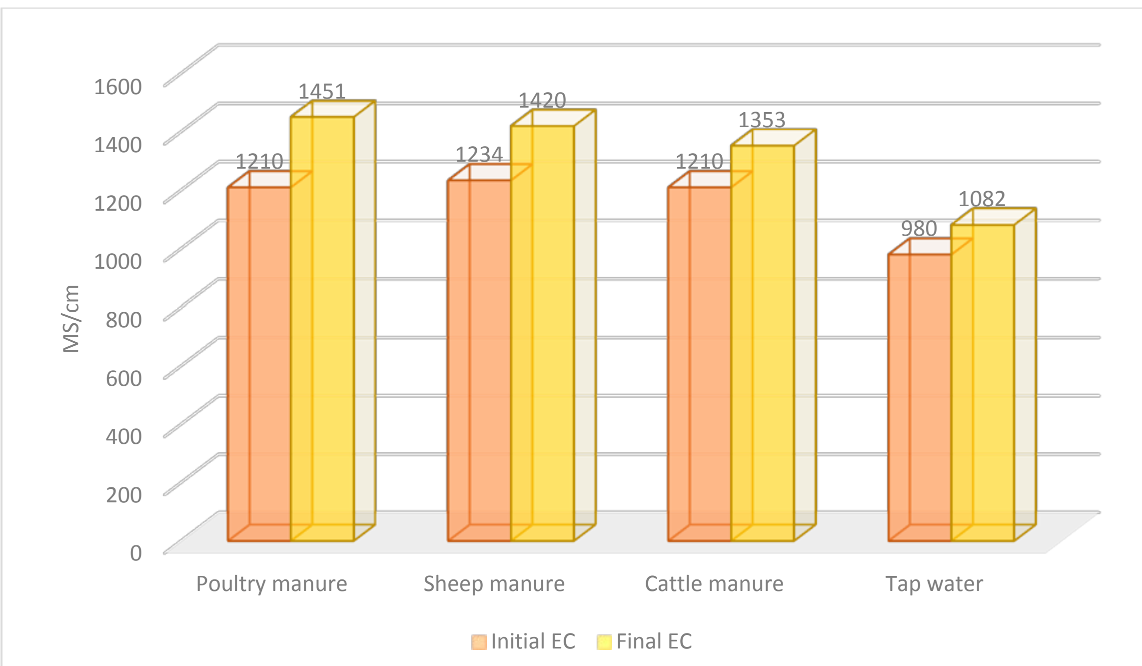

Image 38: 1st dilution EC and EC before embarking on 2nd dilution

The ion concentration in the concentrated solution has an impact on the rise in EC values **(Frasetya et al. 2019).**

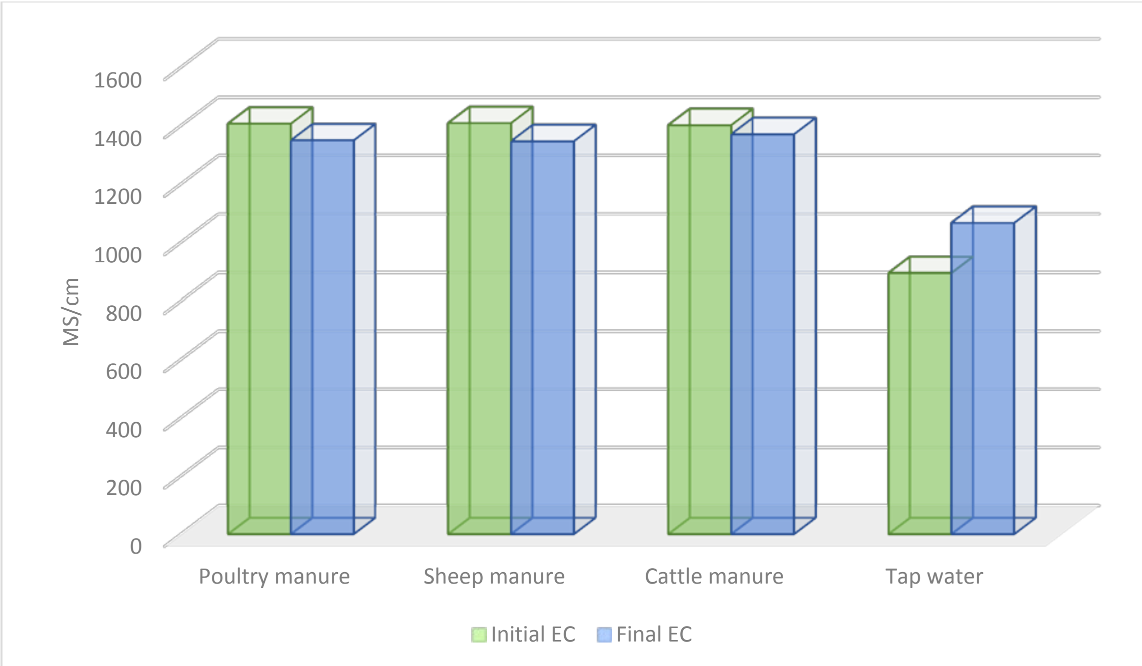

Image 39: 2nd dilution EC and final EC

pH at first dilution stayed in the range between 5,90 and 6,05. At second dilution the range was between 6 and 6,09.

4. Temperature

Solution temperature was at 25℃ at the time of 1st dilution, it dropped to 23℃ at the 2nd dilution.

5. Overall attained growth

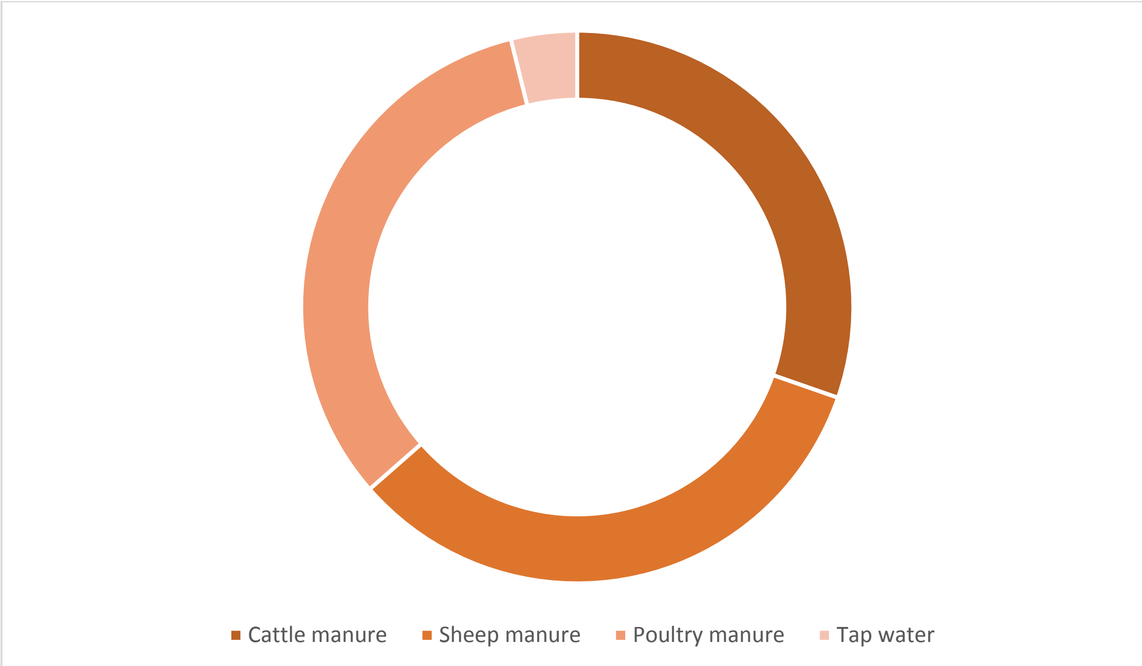

Image 40: Illustration of overall growth attained

CONCLUSION AND RECOMMENDATIONS

For growing lettuce organically in hydroponics system, there is no significant difference in the results obtained from the three different animal manures used in this experiment. This would have a different turn out if chemical fertilisers were being compared, as we see in this differently set up experiment carried out by **Shah et *al*. (2011),** in which Cooper's 1988 nutrients solution recipe of full strength outperformed Imai's 1987 solution recipe for producing tomatoes in a non-circulating hydroponics system. The lettuce grown in tap water was classed least productive because plants need more than just oxygen, carbon and hydrogen. The tap water culture experiment may be insignificant to large scale plant producers but stands as a lesson for home growers trying out hydroponics as a way of growing their vegetables; adding a little organic nutrient solution (even made from kitchen waste compost) may give better results.

Generally the nutrient solution made from sheep manure had a slightly better result appearance with the plants growing therein having the longest leaves and larger width.

In this experiment commendable results were obtained, nevertheless, it was cut short due to high temperatures at the end of the third week, which inevitably wilted the leaves and burnt the roots; future experiments should opt for artificial lighting (LED lights etc.) making it possible to store the plants away from areas susceptible to receiving intense heat from the sun, especially in countries with high summer temperatures like Algeria.

REFERENCES

1. **Aboutalebi, A., Jahromi, M.G. and Farahi, M.H., 2013.** Evaluation of growth and yield of organically-grown basil (Ocimum basilicum L.) in soilless culture. *International journal of food, Helsinki*, *11*(1), pp.299-301.
2. **Ali Al Meselmani M 2023.** Nutrient Solution for Hydroponics. Recent Research and Advances in Soilless Culture. IntechOpen. DOI: 10.5772/intechopen.101604.
3. **Atkin, K. and Nichols, M.A., 2003.** February. Organic hydroponics. In *South Pacific Soilless Culture Conference-SPSCC 648* (pp. 121-127).
4. **Baras, T., 2018.** *DIY hydroponic gardens: How to design and build an inexpensive system for growing plants in water*. Cool Springs Press.
5. **Beibel, J.P., 1960.** Hydroponics -The Science of Growing Crops without Soil‖. Florida Department of Agric. Bull. p. 180,
6. **Bhattacharya, N., 2017.** Hydroponics: Producing plants In-vitro on artificial support medium. *Int. J. Sci. Eng. Res*, *8*, pp.224-229.
7. **Bidaki, S. and Chalavi, V., 2014.** The effect of organic manures in soilless culture on shelf-life extension of strawberry fruit (Fragaria× ananassa Duch. cv. Camarosa). *Journal of Soil and Plant Interactions-Isfahan University of Technology*, *5*(2), pp.107-114.
8. **Birkby, J., 2016.** Vertical farming. *ATTRA sustainable agriculture*, *2*, pp.1-12.
9. Caputo, S., 2022. History, Techniques and Technologies of Soil-Less Cultivation. *Small Scale Soil-less Urban Agriculture in Europe*, pp.45-86.
10. **Costanza, R.; Funtowicz, S.O. and Ravetz, J.R. 1992a.** Assessing and communicating data quality in policy relevant research. Environmental Management 16: 121-131
11. **Costanza, R.; Norton, B.G. and Haskell, B.D. 1992b.** Ecosystem Health: New Goals for Environmental Management. Island Press, Washington, DC., USA.
12. **Di Lorenzo, R., Pisciotta, A., Santamaria, P. and Scariot, V., 2013.** From soil to soil-less in horticulture: quality and typicity. *Italian Journal of Agronomy*, *8*(4), pp.e30-e30.
13. **El-Kazzaz, K.A. and El-Kazzaz, A.A., 2017.** Soilless agriculture a new and advanced method for agriculture development: an introduction. *Agric. Res. Technol. Open Access J*, *3*, pp.63-72.
14. **El-Kazzaz, K.A. and El-Kazzaz, A.A., 2017.** Soilless agriculture a new and advanced method for agriculture development: an introduction. *Agric. Res. Technol. Open Access J*, *3*, pp.63-72.
15. **Frasetya, B., Harisman, K. and Ramdaniah, N.A.H., 2021.** March. The effect of hydroponics systems on the growth of lettuce. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1098, No. 4, p. 042115). IOP Publishing.
16. **Frasetya, B., Subandi, M., Ginandjar, S. and Setiati, Y., 2019.** October. The Effect of Rice Husk Silicate Extract on Plant Height, Electrical Conductivity and pH of Paddy Hydroponics. In *IOP Conference Series: Earth and Environmental Science* (Vol. 334, No. 1, p. 012026). IOP Publishing.
17. **Fussy, A. and Papenbrock, J., 2022.** An overview of soil and soilless cultivation techniques—chances, challenges and the neglected question of sustainability. *Plants*, *11*(9), p.1153.

18. **Gaikwad, D.J. and Maitra, S., 2020.** Hydroponics cultivation of crops. *Protected Cultivation and Smart Agriculture*, pp.279-287.
19. **Gopinath, P., Vethamoni, P.I. and Gomathi, M., 2017.** Aeroponics soilless cultivation system for vegetable crops. *Chem. Sci. Rev. Lett*, *6*(22), pp.838-849.
20. **Goswami, B. and Yadav, V., 2022.** Soil-less culture (hydroponics)—A review. *Just Agric*, *2*, pp.1-12.
21. **Gül, A., Öztan, F., Eroğul, D. and Yagmur, B., 2002.** April. The use of organic manure for iceberg lettuce plants grown in substrates. In *International Symposium on The Horizons of Using Organic Matter and Substrates in Horticulture 608* (pp. 53-57).
22. **Hopkinson S and Harris M 2019.** Effect of pH on Hydroponically Grown Bush Beans (phaseolus vulgaris) Int. J. Environ. Agric. Biotechnol. 4 1 142–145
23. ***Hydroponics - Oklahoma State University*.** 2017. Hydroponics | Oklahoma State University. https://extension.okstate.edu/fact-sheets/hydroponics.html
24. **Kratky, B.A., 2003.** A suspended pot, non-circulating hydroponic method. In *South Pacific Soilless Culture Conference-SPSCC 648* (pp. 83-89).
25. **Kumari, R. and Kumar, R., 2019.** Aeroponics: A review on modern agriculture technology. *Indian Farmer*, *6*(4), pp.286-292.
26. **M. D. S. 2013.** A REVIEW ON PLANT WITHOUT SOIL - HYDROPONICS. International Journal of Research in Engineering and Technology, 02(03), 299–304. https://doi.org/10.15623/ijret.2013.0203013
27. **Maharana, L. and Koul, D.N. 2011.** The emergence of Hydroponics. Yojana (June). 55 : 39-40.
28. **Maikhuri, R.K. and Rao, K.S., 2012.** Soil quality and soil health: A review. *International Journal of Ecology and Environmental Sciences*, *38*(1), pp.19-37.
29. **Mariyappillai, A., Arumugam, G., & Raghavendran, V. B. 2020.** The Techniques of Hydroponic System. *Acta Scientific Agriculture, 4*(7), 79–84. https://doi.org/10.31080/asag.2020.04.0858
30. **Misra, S. and Ghosh, A., 2021.** SOIL-LESS CULTURE FOR HORTICULTURAL CROP. *Agri-IndiaTODAY*.
31. **Mou, B., 2008.** Lettuce. *Vegetables I: Asteraceae, Brassicaceae, Chenopodicaceae, and Cucurbitaceae*, pp.75-116.
32. **Nafiu, M.O., Hamid, A.A., Muritala, H.F. and Adeyemi, S.B., 2017.** Preparation, standardization and quality control of medicinal plants in Africa" In:" Medicinal Spices and Vegetables from Africa: Therapeutic Potential against Metabolic, Inflammatory, Infectious and Systemic Diseases Kuete, V. Academic Press, Elsevier USA.
33. **Nalwade, R. and Mote, T., 2017.** May. Hydroponics farming. In *2017 International Conference on Trends in Electronics and Informatics (ICEI)* (pp. 645-650). IEEE.
34. Resh, H.M., 2016. *Hydroponic tomatoes*. CRC Press.
35. **Sardare, M.D. and Admane, S.V., 2013.** A review on plant without soil-hydroponics. *International Journal of Research in Engineering and Technology*, *2*(3), pp.299-304.

36. **Shah, A.H., Munir, S.U., Amin, N.U. and Shah, S.H., 2011.** Evaluation of two nutrient solutions for growing tomatoes in a non-circulating hydroponics system. *Sarhad J Agric*, *27*(4), pp.557-567.
37. **Shrestha, A. and Dunn, B., 2010.** *Hydroponics*. Oklahoma Cooperative Extension Service.
38. **Singh, D.J. and Davidson, J., 2016.** *Introduction to Hydroponics-Growing Your Plants Without Any Soil*. Mendon Cottage Books.
39. **Son, J.E., Kim, H.J. and Ahn, T.I., 2020.** Hydroponic systems. In *Plant factory* (pp. 273-283). Academic Press.
40. **Thakur, O. and Di Patel, S., Aradhana Dhruw, Dileshwari, Ritika, Aradhana Dhruw 2017.** HYDROPONICS: AN ALTERNATIVE TOOL FOR GROWING CROPS. Inno. Farm, 2(1): 49-51.
41. **Trejo-Téllez, L.I. and Gómez-Merino, F.C., 2012.** Nutrient solutions for hydroponic systems. *Hydroponics-a standard methodology for plant biological researches*, pp.1-22.
42. **Tüzel, Y., Gül, A., Tüzel, I.H. and Öztekin, G.B., 2019.** Different soilless culture systems and their management. *Journal of Agricultural, Food and Environmental Sciences, JAFES*, *73*(3), pp.7-12.
43. **Waiba, K.M., Sharma, P., Sharma, A., Chadha, S. and Kaur, M., 2020.** Soil-less vegetable cultivation: A review. *Journal of Pharmacognosy and Phytochemistry*, *9*(1), pp.631-636.