HIGH SCHOOL EDITION
Journal of Student Research
Volume 11 Issue 2 (2022)

The Effect on the Growth of Lettuce Plants Using Various Recyclable Non-Soil Substrates

Zain Rehman[1] and Jothsna Kethar[#]

[1]Central High School, Springfield, MO, USA
[#]Advisor

ABSTRACT

For a long time now, people have known the devastating effects of soil agriculture. This can include deforestation due to excessive agriculture which increases carbon emissions causing global warming. Previous research emphasized the urgency of developing green sustainable solutions to grow food such as hydroponics and aeroponics. Tron Sherman, of Mansfield, MO, introduced the idea of using a recyclable substrate (i.e., tires) for growing plants. The objective in this study is to determine if lettuce plants will grow better and faster in recyclable substrates using hydroponics as compared to soil. Lettuce plants were selected to grow hydroponically using the Kratky method (defined below) in 7 substrates which included 6 recyclable household materials and one of soil. The best plant from each substrate was selected from height, weight, root length, and width data over the course of 7 weeks. It was found that the best performing substrates in height, weight, root length, and width was found to be cloth and the sponge. All the household recyclable substrates with exception of cushion filling were found to grow plants better than soil. Findings suggest that while rockwool or other commercially available products are used as substrates for hydroponics, recyclable household substrates can be just as effective and better than soil, while reducing cost.

Introduction

For a long time, people have known the devastating effects of intensive agriculture on the environment and have called for a shift in current agricultural practices (Bernard and Lux, 2016). The harmful effects of agriculture include excessive deforestation to create land for agriculture, the application of chemical fertilizers and pesticides to increase crop yield. Previous studies demonstrated that modern agricultural practices contributed 19–29% of global greenhouse gas emissions (Vermeulen, Campbell, Ingram, 2012). Furthermore, previous research emphasized the need for developing sustainable eco-friendly practices for food production (Harvard T.H. CHAN, n.d.). Hydroponics and aeroponics can be a useful alternative option to traditional agricultural practices (Muller et al., 2017).

Previously, Tron Sherman of Mansfield Missouri won a third-place award at the 2009 International Science and Engineering Fair. The title of his project was, “Use of Recycled Tires as Hydroponic Medium”. It was an interesting idea to move away from traditional agriculture toward the hydroponics system to reduce the environmental contamination problems. The current study demonstrates the usefulness of common inexpensive household recyclable substrates to grow plants just as efficiently as soil and other hydroponics commercially available substrates. This creates cheaper options to grow plants right from your home using recyclable substrates. Hence, freeing up space for landfills and reducing land and water pollution. By doing this, people in poverty can grow food more easily for their families and communities, therefore, reducing food insecurity (Folk, 2020).

Objective

This study aims to assess the effectiveness of various household recyclable materials as an alternate option to expensive commercially available hydroponic substrates such as rockwool.

Methods

Little gem lettuce plants were grown using the Kratky Method of Hydroponics (cite ref). The Kratky method is a type of passive hydroponics system that does not need to replace water and nutrients over time (Bulla, 2021). In this method, plants were suspended above a nutrient and water source. In the current study, I evaluated the growth of lettuce in six different recyclable substrates including, pillow filling, rockwool, clothes, mattress foam, cardboard, and sponge. These substrates were chosen because they are porous enough to hold water, give the roots space to absorb air through their aerial roots, and support the plant in water. For comparison purposes, I also grew lettuce plants in soil which is a traditional substrate plant growth. A 1.6 mL solution of the Diamond Blue hydroponic nutrients was added in a 55L plastic tub to supply the plant nutrients such as nitrogen, potassium, and phosphorus. A black sheet of cloth was used to cover the whole tub to prevent algal growth and insects' entry. Finally, the plant height and width were measured on weekly basis for seven weeks. The weight and root lengths were measured once at the end of the 7-week period. Duplicate plants were used for each substrate including soil.

In this study, the little gem lettuce was chosen because it grows fast and was reliable. This plant is reliable as it is known for its sturdiness. A grow light was suspended 6-12 inches from the lettuce plants to provide the necessary light. As the plants grew, the distance of the light was adjusted accordingly.

With Kratky method, all that must be done is to set the system up, and let the plant grow. This reduces labor costs. Growing food hydroponically can help grow food all year long unlike soil agriculture which is season dependent.

Results

Results were collected each week for 7 weeks and integrated into a table. Soil plants were watered twice a week. To measure each materials' plant, a measuring tape and balance scale was used to measure the height, width, weight/yield, and root length of each plant in centimeters. The height was measured from the tallest leaf to the beginning of the roots of each plant. The width was measured by measuring the widest distance from the ends of each leaf. The weight was measured with a triple beam mechanical balance scale. Also, the root length was measured from the base of the plant to the end of the biggest root. The plants in the soil substrate were watered twice a week.

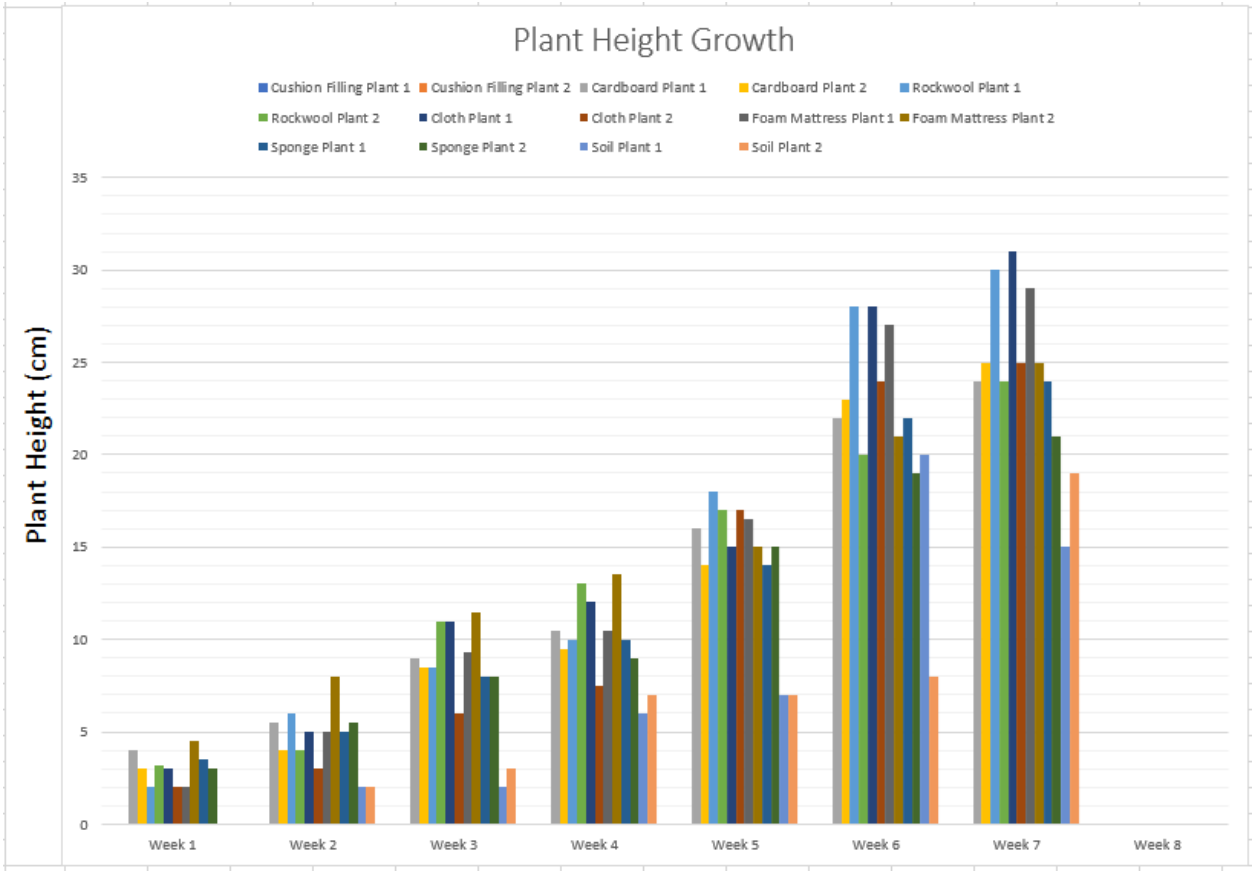

Figure 1. Plant Height Growth over time.

As Figure 1 above shows, data of two plants in each substrate were collected and the height were recorded weekly. This chart compares the height of each substrate over each week. This graph shows that the cloth plant 1 was the tallest of all the plants. The cushion filling did not allow the lettuce plant to germinate.

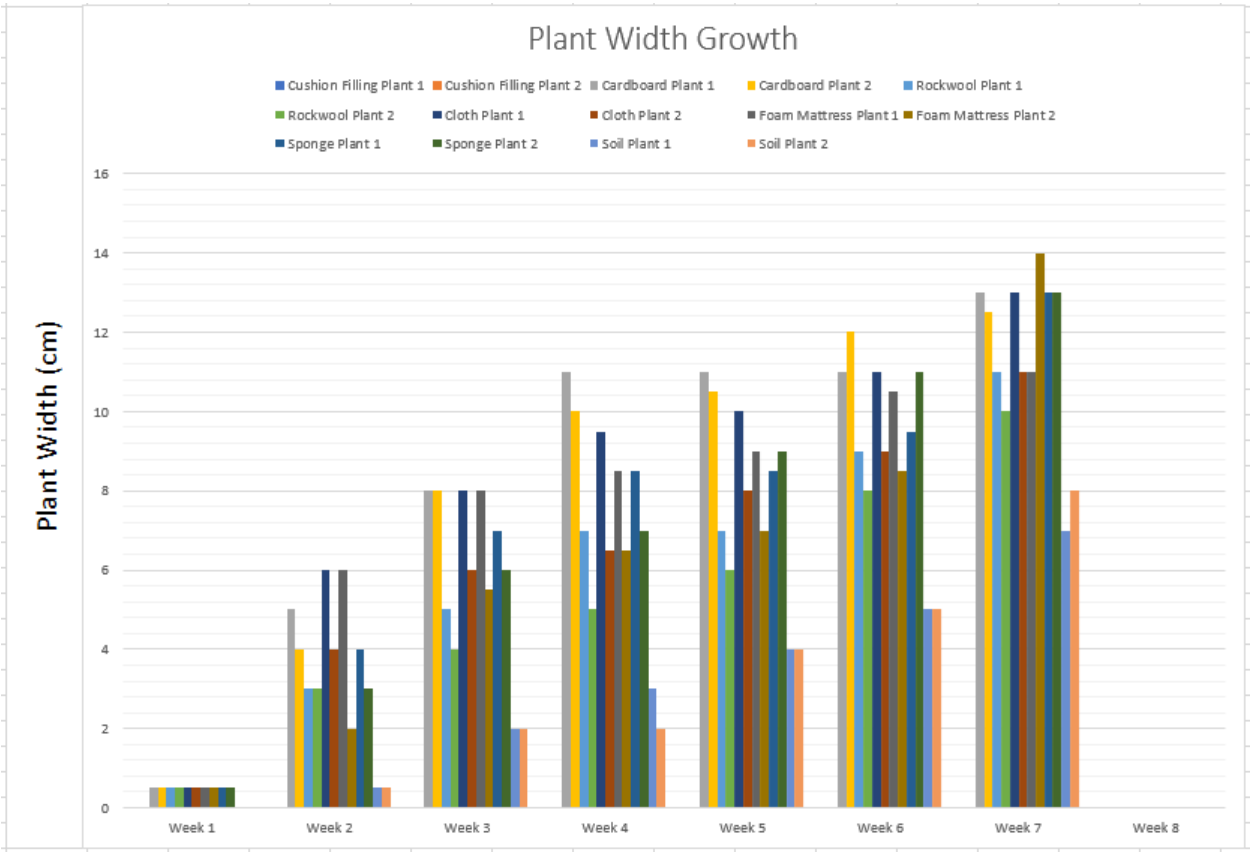

Figure 2. Plant Width Growth over time.

As shown in the Figure 2, this chart compares the width of each plant. The width was used for measuring the health of these plants. The plant with the most width was plant 2 in the foam mattress substrate.

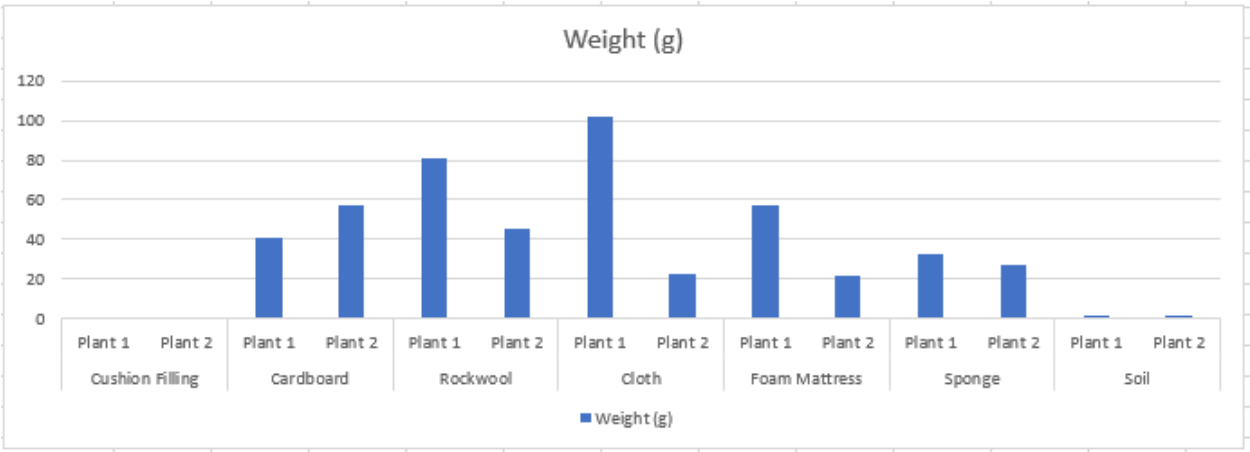

Figure 3. Plant Weight at the end of seven weeks.

Figure 3 is once again showing that the recyclable substrates did better than the soil. The one exception being the cushion filling. This chart is showing the yield of each of the plants for each substrate. The plant that had the most yield was plant 1 of the cloth substrate. The more weight means more lettuce, so this chart is essentially showing which plant grew the most lettuce.

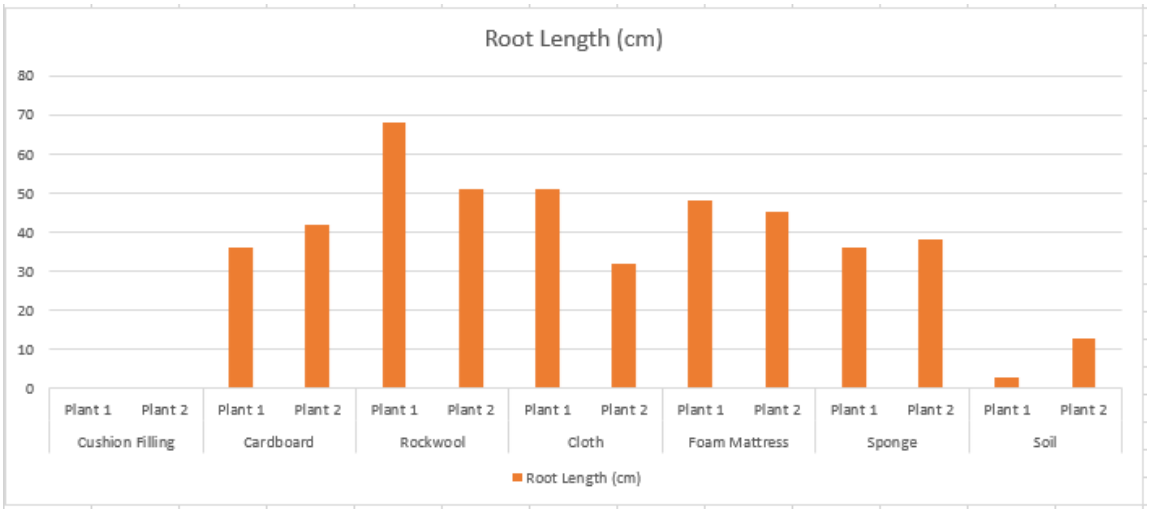

Figure 4. Root Length at the end of 7 weeks.

Figure 4 shows that plant 1 of rockwool had the longest root length. Nevertheless, the more cost-efficient substrates did well too. The root length is essentially a way of measuring the plants' health. This means that plant 1 in rockwool had the best health out of all the plants.

Discussion

In the results section, it was concluded that most of these recyclable substrates were more efficient and effective than the soil substrate, especially the cloth. Interestingly, plants with these recyclable substrates appeared to be growing faster, healthier, and more root strong. These substrates provided better support than the soil. Additionally, the yield of the crop in the recyclable substrate was more compared to in the soil. Further experiments are needed to make this idea more mainstream to help families and communities grow food easily and cheaply to move away from soil farming and reverse all the damage caused by the agricultural revolution back in the 1700s.

The data compared in these substrates was substantial compared to the data in the soil. The plants that grew in the recyclable substrates were more healthy and taller than both soil plants. The rockwool, which was more expensive than the other substrates, was less effective than the cheaper and recyclable substrates.

In terms of germination, all the substrates were able to germinate their respective plants except for the cushion filling. This is because the cushion filling could not grow its plant due to its lack of porosity. Since the cushion filling was made of multiple strings, the substrate could not hold the water with nutrients. The cloth did the best at the point of germination as it had the greatest height and width. This is because it had the most porosity out of all the plants. These recyclable substrates did the best at germination for their respective plants.

As seen in the results section, the yield of the plant was recorded. The yield is the weight of each plant. Figure 3 above shows that plant 1 of cloth grew the most lettuce. This is most likely because the cloth allowed the lettuce to grow the most. The cloth allowed the plants to grow the best as it was most likely the most porous substrate of them all. The more porous the growing media is, the more yield the plant can produce.

Overall, these recyclable substrates performed better compared to the more expensive and traditional substrates such as rockwool which is a commercial product.

The main advantage of cloth, sponge, and mattress foam was their high porosity to hold air and water promoting growth of plants.

A major disadvantage of the Cushion filling was its low porosity and ability to retain water which prevented seed germination and plant growth.

This study also shows the potential of lettuce grown in recyclable materials could reach a commercially relevant yield of lettuce crop but further research with a larger sample size is needed to prove this.

Since germination was effective as well, these substrates could be incorporated as a long-life material for sustainable cost-effective hydroponics system for year-round crop cycle farming.

This experiment helps tackle big problems simplistically, and if everyone started doing this it would improve living conditions. Doing this can also help prevent carbon emissions from escaping into the atmosphere, prevent land pollution, prevent deforestation, and reduce poverty. By using recyclable substrates for hydroponics, deforestation due to agriculture can be prevented, which passively reduces carbon emissions. This can reduce poverty as it is an easy way to grow (and eventually sell) food. This study can prevent many world issues.

Thus, more research is needed to identify the ideal porosity needed in different household recyclable materials that can provide adequate conditions for plant growth. Also, future direction of this research can investigate perhaps changing the size of the particles of each substrate to increase their porosity allowing for better root development and potential increase water retention capability and therefore the yield of lettuce.

This study could potentially change the course of hydroponics forever. This method of growing plants is essentially an upgraded version of the Kratky Method of Hydroponics. Instead of using expensive substrates, we used recyclable substrates that are easy to find and cost-effective.

Plants need nitrogen, potassium, and phosphorus besides water and sunlight to grow. The nutrients solution used was the Diamond Blue hydroponic nutrients. About 1.6 milliliters per liter of the nutrient solution was mixed in fifty-five liters of water held in a plastic tub.

To prevent the algae from growing in the water and depleting the nutrients in it, a black sheet of cloth was used to cover the whole tub.

The top of the tub was covered with a lid to prevent sunlight from getting into the water as well as mosquitoes and other insects laying eggs in it thereby avoiding infestations.

Instead, all that must be done is to set the system up, and let the plant grow, therefore reducing labor costs. Growing food hydroponically can help grow food all year long unlike soil agriculture which is season dependent.

Conclusion

While rockwool or other commercially available products are used as substrates for hydroponics, recyclable household substrates can be just as effective and better than rockwool and soil, while reducing cost. These materials are durable substrates that can be reused over multiple crop cycles for hydroponic food production at home easily.

Limitations

The limitations in our project include the sample size of the plants, the equipment used to measure water qualities, timing of collected data, and qualitative analysis of plant growth. If we were to use a larger sample size,

it would decrease the chance of recording incorrect data, hence incorrect analyses.

Acknowledgments

I would like to thank the following individuals for their guidance and mentorship during this research process.

- Dr. Dominique Rajagopal
- Mrs. Jothsna Kethar
- Mrs. Denise Vinton
- Dr. Babur S. Mirza

References

Bernard, B., & Lux, A. (2016, July 27). How to feed the world sustainably: an overview of the discourse on agroecology and sustainable intensification. *Regional Environmental Change*, *17*, 1279-1290. https://doi.org/10.1007/s10113-016-1027-y

Bulla, A. (n.d.). *The Kratky Method: Growing with Passive Hydroponic Technique*. Gardening Chores. https://www.gardeningchores.com/kratky-method/

Folk, E. (2020, August 29). *Hydroponics part 1: Growing the food we need without dirt*. Red Green and Blue. https://redgreenandblue.org/2020/08/29/hydroponics-growing-food-need-without-dirt/

Harvard T.H. CHAN | School of Public Health. (n.d.). The Nutrition Source. https://www.hsph.harvard.edu/nutritionsource/sustainability/

Muller, A., Ferre, M., Engel, S., Gattinger, A., Holzkamper, A., Huber, R., Muller, M., & Six, J. (2017). Can soil-less crop production be a sustainable option for soil conservation and future agriculture? *Land Use Policy*, *69*(C), 102-105. https://doi.org/10.1016/j.landusepol.2017.09.014

Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. (2012, July 30). Climate Change and Food Systems. *Annual Reviews*, 195. https://doi.org/10.1146/annurev-environ-020411-130608