3D Printed hydroponic system

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ABSTRACT

Hydroponic systems have been around for many years and there is a large variety of designs. This project approaches the design of a stackable hydroponic system for domestic use aiming for high yield. The 3-D printed prototype consisted of cylindrical elements each with three entries for seeding. These elements can be stacked up and rotated around one another providing configuration flexibility. In addition, the cap of our system is a half cylindrical element. A preliminary test included the use of Rockwool to grow coriander for 14 days. Being a prototype, it is still necessary to optimize the design, fine-tune its operation beyond its initial feasibility to both, maximize yield and minimize cost, which implies compromising on these two conflicting objectives.

KEYWORDS

Hydroponic Systems, 3D Printed Systems, Vertical Hydroponics.

RESUMEN

Los sistemas hidropónicos existen desde hace ya varios años en una amplia variedad de diseños y configuraciones. El proyecto que aquí se describe comprende el diseño de un sistema hidropónico modular apilable para uso doméstico, con miras a que sea uno con alta productividad. Una impresora 3D se utilizó para desarrollar el prototipo que consta de elementos cilíndricos, cada uno con tres receptáculos. A los elementos cilíndricos apilables se les puede rotar con respecto de su eje, añadiendo así mayor flexibilidad de configuración. Convenientemente, la tapa del sistema está formada por medio elemento cilíndrico. Para la prueba preliminar que aquí se describe, se depositaron semillas de cilantro por un período de 14 días en Rockwool. En su fase prototípica, se determinó la factibilidad del sistema, aunque se reconoce que es aún necesario optimizar el diseño y afinar su operación. Esto implicará conciliar dos objetivos en conflicto: maximizar la productividad del sistema y minimizar su costo total.

PALABRAS CLAVE

Hydroponic systems, 3D Printed, optimization, maximize.

INTRODUCTION

A hydroponic system provides a soil free environment for the appropriate growth of plants. Since no soil is involved, one must provide into the system the nutrients that normally soil provides. Nonetheless, it is an efficient method for growing plants that can be used for plant studies, and commercial or domestic use. The term was first coined by William F. Gericke in 1929, yet it is a documented technique dating back to the late 17th century. Its advantages include the potential for accessibility to all plant tissues and the easy manipulation of the nutrient profile of the growth medium when compared to soil, given the complex interaction of ions with soil particles (Conn; et all, 2013). As an initial aim in this project it is desired to provide a hydroponic system focusing on high yields and low costs, contrasting with what is already commercially available. Traditional systems are usually assembled with Polyvinyl Chloride (PVC) pipes and usually require additional materials, machinery, and space for it to run properly. This can be a problem for people with modest budget who are interested on hydroponic systems, especially for a domestic use. A non-traditional vertical system was designed, and its parts were printed with the aid of a MakerBot 3D printer. Having a vertical drop system saves space and the costs associated to a traditional system, providing an alternative that can be plausible for a near future. The completion on our project would be for this system to be available for anyone who is interested in hydroponics and wants to avoid the hassle of the traditional assembly.

Methodology

Before starting the design and manufacturing process, we investigated what hydroponics were as well as their main purpose. We managed to find multiple types of hydroponic systems, but the most common was that of the horizontal type made out of PVC. However, there were also vertical versions that caught our attention since they seemed to allow more yield and occupied vertical space instead of horizontal space. Once we established the type of system to design, we used Autodesk Fusion 360 to such end. While designing, we had to take into account the dimensional limits of our 3D printer (height, length and depth). After many iterations we decided that the main body had to have a diameter of 80mm and that the features coming out of the main body -to contain initially the rockwool and subsequently the plants- would have a diameter of 64mm at an angle of 45 degrees. We also set the height of the single piece to be 140mm. The pieces were also designed with the ability to be stacked. Two almost identical designs were printed, the only difference being that a varying number of protrusions came out of the main body. We chose to keep the number of holes in the body low to keep the plant roots from clogging up the system. After our design specifications were set, we printed a small-scale replica to make sure that two cylinders fit together and that there were no errors in the printed part. Once all the details were sorted out, we started to print the parts at full scale. Each main part took around 5.5 hours to print.

We used a variety of materials to create the vertical hydroponic system with a MakerBot Replicator 2 3D Printer. The filament used to print was PLA 1.75mm which is non-toxic. To complement the printed parts, we added a commercially available water pump, a solar panel to energize the pump, a 1-gallon plastic container with lid (since the container was very clear we applied black spray paint to avoid algae), and a clear vinyl tube. For our first run we decided to plant coriander. The seeds were germinated (2-week process) on Rockwool with only water (twice a day; very important to keep Rockwool hydrated), no nutrients were added during this step. After the germination process, we used 11-11-40 fertilizer specialized for coriander. We also added Ca and Mg, both critical for maintaining a neutral pH on the water reservoir and as factors to potentially add flavor to our final product.

The Rockwool with seeds were transferred to the system on the 18th of February, 2019 as shown in figure 1. They took about two weeks to start sprouting. Once on the vertical tower, plants were watered continuously from 10AM until ~5PM for the next 21 days. figure 2 shows the system after 21 days.

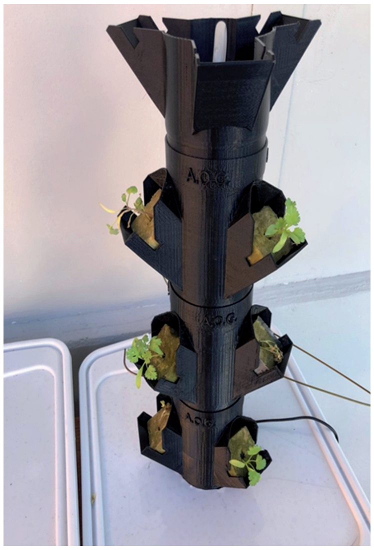

Fig. 1. Day 1 in 3D system.

Fig. 2. Day 21 in 3D system.

RESULTS

Our preliminary results showed that the 3-D Printed Hydroponic system did aid in the growth of the coriander plant. The plant grew substantially in the first 3 weeks on the tower. Its color was to our satisfaction and so was the aroma. We did notice that the flavor was rather mild. A possible downside of this first run was that the plant was exposed to all types of weather conditions, but we cannot conclude if it had any positive or negative effect on growth. Water temperature was also high during mid-day which might have contributed to an increased evaporation rate of the water in the system.

Table I. Final Height of the Coriander (1st run).

Sample	Leaf Height (mm)	Final Plant Height (mm)	Leaf Width (mm)
1	25.91	68.33	25.40
2	22.86	90.93	29.72
3	29.72	75.69	34.04
4	23.11	66.80	23.37
5	26.42	37.34	17.78

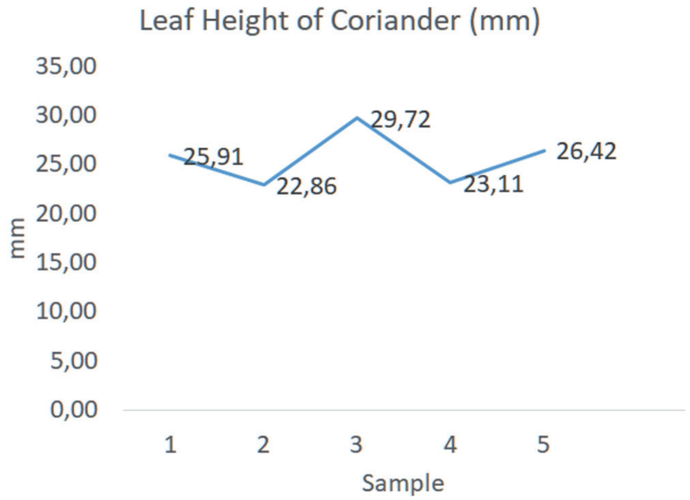

Fig. 3. Leaf Height of the Coriander (1st run).

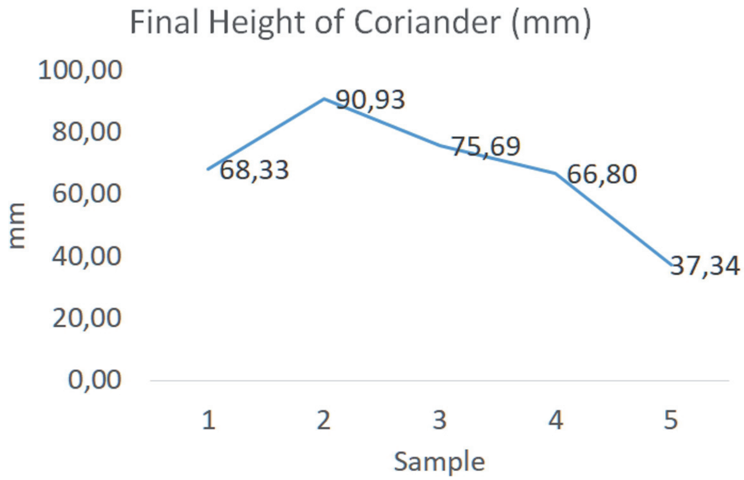

Fig. 4. Final Height of the Coriander plant (1st run).

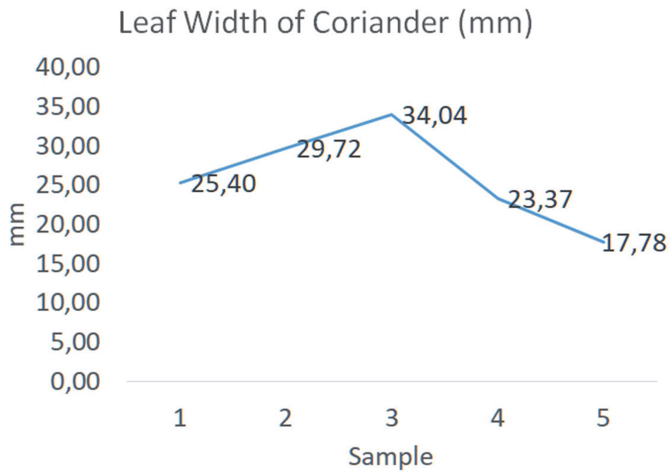

Fig. 5. Leaf Width of Coriander (1st run).

For the results shown in figures 3,4, and 5, five plants from each system were chosen with consistent results. On figures 4 and 5, sample 5 tends to be an outlier, which may be due to the exposure by the plants to all types of weather conditions as mentioned previously. For a comparison of the costs of the 3D printed system vs a conventional PVC one, please note table II.

Table II. Costs of the 3D Printed System vs. Traditional System (under the assumption that a 3D printer is at hand). Units are US dollars.

Parts and each cost of the materials used for the 3D Printed System. Fits nine plants.	Seeds: $1.50 (per pack).	If one were to buy a traditional hydroponic and all the equipment needed to grow coriander, the cost would fluctuate around $90.00 to be able to run 9 Coriander plants.
	MakerBot Filament: $25.99, this would be $6.50 per unit (each unit fits 3 plants).	
	1-gallon Plastic Container $4.00.	
	Rockwool: $9.95 for the pack of 48 (0.21 cents per unit).	
	PVC Clear Vinyl Tube: $4.46 for 10ft.	
	Spray Paint $3.00	
	Solar Water Pump: pumps 2' of water. $10.00.	
	Total Cost for 3D Printed System would be $55.00.	

CONCLUSIONS

Noted as part of our results, our system proved feasible although in need of subsequent optimization. One important future aim will be the enhancement of product flavor. We are sure that our system lacked a proper mixture of nutrients and vitamins that would require more knowledge in agriculture. A proper mixture experiment could alleviate this.

Contrasting to a traditional hydroponic system we can add that the 3-D printed design does not have problems of loss of water, it is easy to assemble, and its costs are comparatively lower to a conventional commercially-available PVC hydroponics system.

This of course, considering that a 3D printer is already at hand, which may not hold true in general terms. Nowadays such equipment can be found for a price as low as $400 US dollars, so planning to use multiple hydroponics units can help offset this cost.

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