THE CLSU INTERNATIONAL
JOURNAL OF SCIENCE & TECHNOLOGY

Volume 2, No. 2: 1-7 (2017)
www.clsu-ijst.org

ISSN 2507-9368

DOI: 10.22137/ijst.2017.v2n2.01

Design and Fabrication of a Pyramid- Type Plant Bed Hydroponics of Romaine Lettuce Production under Lowland Condition

Marvin T. Valentin, Rakim B. Casnor, Jomel C. Fanwa, and Vincent S. Dangan

Department of Agricultural and Biosystems Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines
Email for correspondence: m_valentin14@yahoo.com

Submitted June 2017, Accepted October 2017, Published online December 2017

ABSTRACT

This study aims to design and fabricate a pyramid- type plant bed hydroponics under lowland, open-field condition. The hydroponics system recirculates a total volume of 150 liters of nutrient solution with an average flow rate of 33.33 milliliter per second and was designed to hold a capacity of 100 plants with 20 cm spacing.

The fabricated pyramid-type plant bed hydroponics has an area utilization efficiency of. 169.49 percent. The prototype was tested on romaine lettuce. A commercial liquid bio-fertilizer was used as a liquid solution in the study with a concentration of 1:100. However, the plants only lasted for 15 days and had no significant yield.

The newly designed hydroponic grow bed system is recommended for further evaluation considering the nutrient requirement of the test plants.

Key Words: design, fabrication, hydroponics, prototype, area utilization efficiency

INTRODUCTION

Hydroponics (Greek words 'hydro' water and 'ponos' labour) is a method of growing plants using mineral nutrient solutions without soil. It is also called as "controlled environment agriculture" (CEA) since raising plants hydroponically requires control of environmental factors such as light intensity and duration, temperature, humidity, pH of the solution/medium and mineral nutrients (Pandey et al., 2012).

On the other hand, vertical farming refers to the cultivation of plant life on vertically inclined surfaces, minimizing land footprint by stacking upwards instead of outwards as opposed to conventional farming. Vertical farming can provide an intensive growing method in urban spaces, offering much higher yields per acre than conventional production techniques (Ackerman, 2015 as cited by Association for Vertical Farming, 2015). Vertical farming then gave birth to the concept of pyramid gardening. Pyramid gardening is a new innovative concept of growing plants in a pyramid structures to maximize the use of space. One fine example of pyramid gardening is "The Pyramid Farm". The Pyramid Farm is a design of a vertical farm envisioned by professors Eric Ellingsen and Dickson Despommier for the future of agriculture. The design is based on the growing belief that vertical farming will soon become a necessary lifeline in cities throughout the world (Kain, 2009).

The objective of the study was to design and construct pyramid hydroponic system that integrates the concept of hydroponics and pyramid gardening into a pyramid-type plant bed hydroponics. The hydroponics system was to be evaluated in a lowland, open-field condition using a romaine lettuce as a test crop.

MATERIALS AND METHODS

Design consideration. The flow rate was the major consideration in the design of the hydroponics system. In this case, the flow rate would be a function of the velocity of the liquid solution recirculating through the system and the cross-sectional area of the PVC pipe to be used. Also, selection of appropriate materials was much importance in the design of the system. Materials used were of good quality and are locally available.

Conceptual framework of the study. The study was subdivided into two phases for easy facilitation and smooth transition through various tasks involved in the study (Figure 1). Phase 1 was the design, fabrication, and initial evaluation of the hydroponics system. Phase 2 involved the evaluation of the test crop, which in this case a Romaine lettuce, in the hydroponics system at lowland, open field condition at CLSU Compound, Science City Munoz, Nueva Ecija.

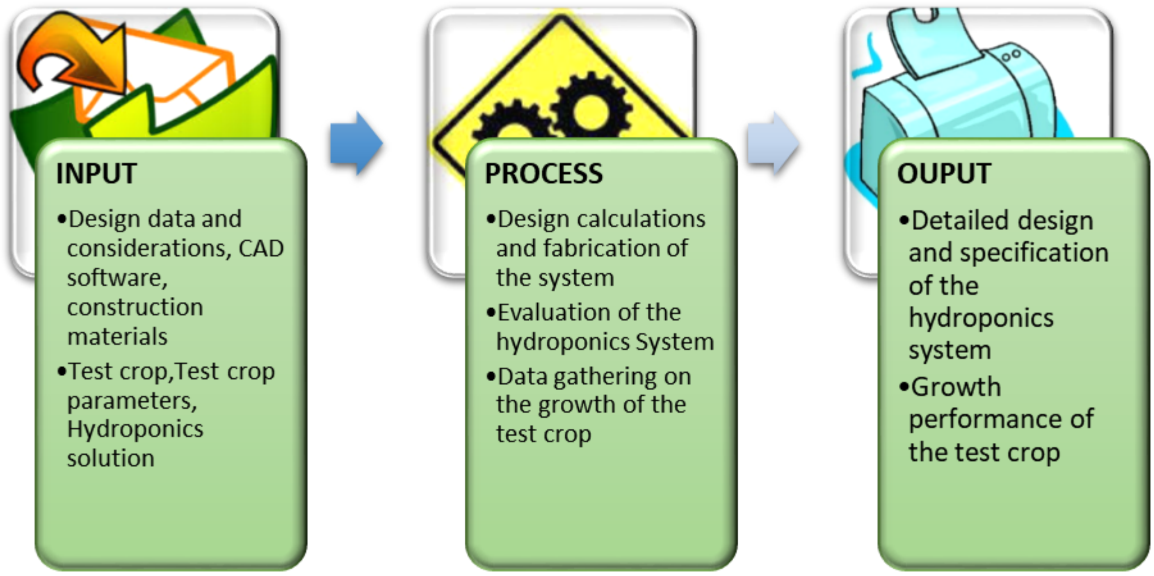

Figure 1. Conceptual framework of the study

Design of the Hydroponics System. After initial design assumptions and considerations, design calculations were done intensively throughout the study to lay down the basic design concepts of the study. The results were verified and simulated using Computer Aided Design (CAD).

The design calculations were guided by the equations provided below. The power required to push water with nutrient solution on the system is given in equation 1. Equation 2 was used to calculate volume flow rate of water on the system.

$$P = \rho g Q h \qquad (1)$$

where:

P=power required, KW
Q=Volume flow rate at the drive pipe, m^3/s
G=gravitational force, 9.81 m/s^2
H=total head, m
ρ=density of water, kg/m^3

$$Q = Av \qquad (2)$$

where:

Q = liquid flow rate (m3/s or L/s)
A = area of the pipe or channel (m2)
v = velocity of the liquid (m/s)

Principle of operation. The proposed hydroponics system was composed of the following components: square-shaped plant beds made out of PVC pipes, steel frame, a 50-liter capacity plastic barrel placed at the top of the steel frame, 100-liter capacity plastic tank placed at the bottom of the system, submersible pump, and plastic cups that holds the plant along with its media.

The system works by pumping the nutrient solution from the 100-liter capacity plastic tank at the bottom to the 50-liter capacity plastic barrel at the top. From the plastic barrel, the liquid solution flows down by gravity to the first layer of plant bed through a ½ inch PVC pipe. From the first layer of plant bed, the liquid solution flows down to the succeeding layers via the drain hoses installed in each plant bed layers until it reaches the 100-liter capacity plastic tank and recirculates again.

Source of specimens. Two-week old Romaine lettuce seedlings from La Trinidad, Benguet, Philippines were used during the study. Romaine or "cos lettuce" is a variety of lettuce (Lactuca sativa L. var. longifolia) that grows in a tall head of sturdy leaves with firm ribs down their centers. Unlike most lettuces, it is tolerant of heat (Wikipedia, 2017). Due to difference in climatic conditions between the place of study and the source of the seedlings, and stress incurred during the transport, the lettuce seedlings were allowed to harden for five (5) days before transplanting in the hydroponic system.

Commercialized coco peat (COCO DUST PLUS) available at local agricultural supplies was used in the study. Coir dust is a lightweight material and porous material having a total porosity above 94 percent (by volume) (Abad et al, 2005). A bio-liquid fertilizer (Bio Cium) was used as the nutrient solution for the hydroponics system with a concentration of 1:100. A weekly application rate was recommended by the manufacturer of the bio-liquid fertilizer.

Construction of the Hydroponics System. The design process continued even in the construction of the system since some revisions of the initial design were done during the actual construction. Equipment like welding machine, drill press, portable drill, portable grinder, hydraulic press and cutter were used during the construction process. The construction of the hydroponic system was then carried out the following the process: (1) measuring, marking out and cutting various parts of steel bars and PVC pipes; (2) drilling the holes of plant bed, tanks and steel bars; (3) joining parts through weld, bolts and nuts; an (4) assembly, finishing and aesthetics.

RESULTS AND DISCUSSION

Output design

Shown in Figure 2 is the output design of the hydroponic system. It comprises five (5) layers of planting bed arranged in pyramid through the frame. The planting bed is made up of PV pipe (3 in diameter). A filter is also designed and placed at the highest part of the system which will first receive the liquid solution form the water tank placed at the bottom of the pyramid.

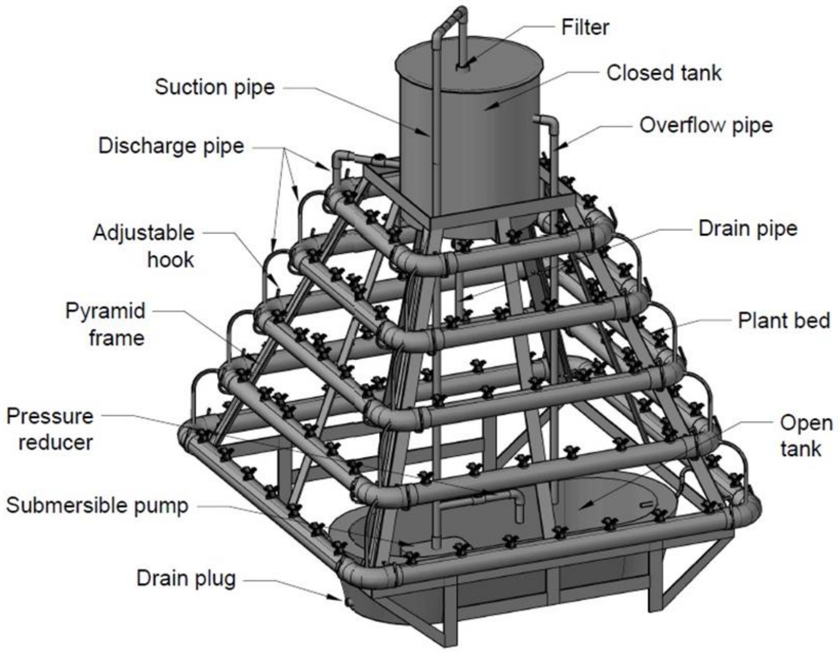

Figure 2. Schematic diagram of the Pyramid- Type Plant Bed Hydroponics

Fabricated Hydroponics Set-up

The actual fabricated design of the hydroponics system and some of the actual fabrication process was shown in Figure 3.

Figure 3. Construction of the Pyramid- Type Plant Bed Hydroponic

The resulting hydroponics system was a pyramid-type plant bed hydroponics system. The hydroponic system has a total height of 7 ft. and a base covering an area of 25 ft^2. From repeated measurements, the system recirculates a total volume of 150 liters of nutrient solution with an average flow rate of 33.33 milliliter per second. It has also five layers of plant beds which was designed to hold a capacity of 100 plants with 20 cm spacing. Comparing this result with the conventional farming, the designed hydroponics system has a significant edge in terms of yield produced per unit area. Using 20 cm × 20 cm spacing in the conventional farming, the maximum number of plants that can be planted in a 25 ft^2 lot was computed to be 59 plants, whereas, the designed hydroponics system can hold 100 plants with the same area. This is almost 70 percent increase in the maximum yield per unit area with the use of the designed hydroponics system. Other technical specifications of the resulting hydroponics system were presented in the Table 1.

The only drawback of the designed hydroponics design is the possibility that waterlogging to the plants may occur since the plant are exposed to the nutrient solution for 24 hours. The square-shaped plant beds of the hydroponic system were designed to store nutrient solution. This feature allowed the plants to have continuous supply of nutrient solution even in power interruptions when the pump does not work. Other pros and cons of the hydroponics system were presented in Table 2.

Table 1. Table of specification

MAIN STRUCTURE	
Frame	
Area covered, ft^2	25
Length, ft.	5
Width, ft.	5
Material	1 ½ " × 1 ½ " × 3/16 " angle bar
Fastener	12 mm Hex Bolt
Plant Beds	Total no. of plants
1st Layer	12
2nd Layer	16
3rd Layer	20
4th Layer	24
5th Layer	28
Total Capacity	100
Material	PVC pipe
Tanks	Capacity
Plastic barrel	50 liters
Plastic tank	100 liters

Table 2. Pros and cons of the designed Hydroponics System

Advantage	Limitations
• Easily assembled and dissaembled • have continuous supply of nutrient solution even during power interruptions • higher maximum yield per unit area compared to conventional farming	• The possibility of waterlogging may occur • High operating cost compared to conventional farming • High initial cost compared to conventional farming • requires technical knowledge on hydroponics

Performance of the test plants

Prior to the transplanting, the Romaine lettuce was hardened for five days to allow it to adjust the lowland condition. The average height of the lettuce seedlings was measured to be 9.5 cm during transplanting. It was observed that during the first four (4) days the lettuce did fare well showing positive signs but in the fifth day the lettuce started to show signs of wilting. This condition of the plants persisted until the 7th day where 100% mortality of the plants occurred. There are many factors that may have caused the mortality of the Romaine lettuce but as it was observed the primary cause may have been the prevailing climatic condition in the lowlands and the concentration of the nutrient solution. According to Frost (2010), lettuce grows best when temperatures do not exceed 75°F (23.89 °C) but it was found that the highest temperature during the plant was grown in the hydroponics system was at 42°C and an average temperature of 40°C. Another factor that may have caused of the mortality of the test crop would be the growing media used. Coco peat is very lightweight and porous material, and may indeed provide a good aeration for plants but it has low easily available and total water holding- capacity which ranged from < 1% to 36% by volume and from 137 to 186 ml.L^{-1} (Abad et al, 2005). The set-up of the lettuce in the hydroponics system is shown in Figure 4.

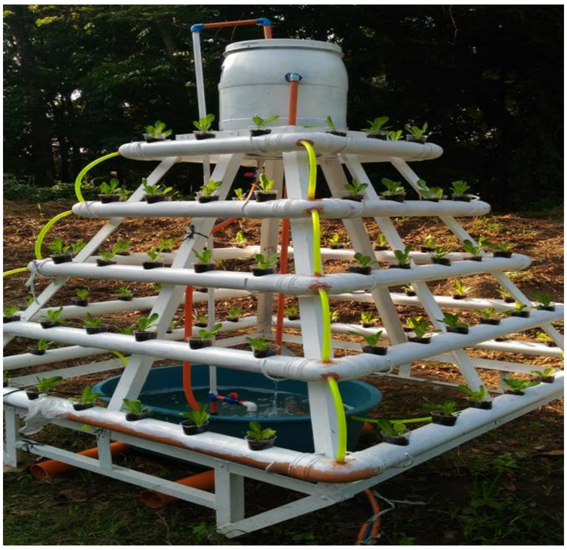

Figure 4. Set-up of the Pyramid- Type Plant Bed Hydroponics

Vol. 2 No. 2 (December 2017) | ISSN: 2507-9638 | DOI: 10.22137/ijst.2017.v2n2.01

CONCLUSION

The research was focused on the design and construction of pyramid-type plant bed hydroponics which helps maximize the use of space and the evaluation of hydroponically grown Romaine lettuce in an open field condition. Results revealed that using the pyramid-type plant bed hydroponics increases the maximum yield per unit area to almost 70 percent compared to conventional farming. The results of the study also revealed that hydroponically grown Romaine lettuce in a pyramid-type plant bed hydroponics did not thrive well in a lowland, open-field condition.

REFERENCES

Abad, M. et al. 2005. Physical properties of various coconut coir dusts compared to peat. Valencia, Spain. Accessed December 20, 2017. http://hortsci.ashspublications.org/content/40/7/2138.full.pdf.

Association of Vertical Farming. 2015. Sustainability certification for indoor urban and vertical Farms. Accessed May 20, 2017. http://sustainability.ei.columbia.edu/files/2016/01/Sustainability-Certification-for-Indoor-Urban-and-Vertical-Farms.pdf.

Frost, D. 2010. Lettuce in the garden. Utah State University. Accessed December 20, 2017. http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1248&context=extension_curall.

Kain, A. 2009. Pyramid farm is a vision of Vertical Agriculture for 2060. Accessed May 20, 2017. http://inhabitat.com/pyramid-farm-vertical-agriculture-for-2060.

Pandey, R. 2009. Hydroponics Agriculture: Its status, scope, and limitations. Indian Agricultural Research Institute, New Delhi. Accessed December 20, 2016. https://www.researchgate.net/publication/259786326.

Wikipedia.________. Romaine Lettuce. Accessed December 20, 2016. https://en.wikipedia.org/wiki/Romaine_lettuce.