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Design and Construction of a Vertical Hydroponic System with Semi-Continuous and Continuous Nutrient Cycling

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Abstract. Problems due to the increase in agricultural land use change can be solved by hydroponic system applications. Many hydroponic studies have been conducted in several countries while their applications in Indonesia requires modification and adjustment. This research was conducted to design and construct a hydroponic system with semi-continuous and continuous nutrition systems. The hydroponic system which was used adapts the ebb and flow system, and the nutrient film technique (NFT). This hydroponic system was made from polyvinyl chloride (PVC) pipes with a length of 197 cm, a diameter of 16 cm, and a slope of 4°. It was constructed from four PVC pipes. In semi-continuous irrigation treatment, nutrients flow four to six times for each of ten minutes depending on plant development and the estimated evapotranspiration occurring, while in a continuous nutrient system the nutrients are streamed for twenty-four hours without stopping at a maximum flow rate of 13.7 L per second.

INTRODUCTION

Generally, a growing population in a country encourages its economic growth. The rate of social and economic (socio-economic) growth significantly increases the demands for land availability for infrastructure development, for example in the form of public facilities such as roads, buildings for industry, offices, and settlements, as well as tourist attractions. The rapid development that supports the economic sector mainly causes the conversion of agricultural land to non-agricultural usage.[1,2] Land conversion contributes to the development of agricultural land and indirectly leads to soil fertility degradation. In addition, the conversion of agricultural land into residential areas/housing is considered more financially profitable so that more agricultural lands switch their functions. This phenomenon causes a drastic decrease in agriculture productivity. Land conversion also causes pollution, especially land pollution due to rapid development that indirectly affects the degradation of soil fertility. [3] Land conversion can be a serious threat to the sustainability of the agricultural sector, which will have an impact on national food security.[2,4]

The tendency for increasing conversion of agricultural land into non-agricultural land requires the creativity of agricultural activists to solve this problem. Currently, the transformation of narrow land as productive land is a challenge. The application of appropriate technologies to help improve the quality and quantity of agricultural products from limited land have been assessed. The vertical hydroponic system in a narrow field is one of the technologies that could be applied. [5]

Hydroponics is the cultivation of plants by utilizing water with or without the use of aggregates and emphasizing the provision of nutrients for plants. In the use of aggregates, several growth media may be used to serve as the plant proponents and the nutrient solution mediators. The growth media might be made from husk coal, sponge, cocopeat, sand, expanded clay, rockwool, vermiculite, moss, wood powder, and stem fern.[6] Plant cultivation using a hydroponic system could also be done with several other methods such as static solution culture, continuous-flow solution culture, aeroponics, passive sub-irrigation, ebb and flow, or flood and drain sub-irrigation, run-to-waste, deep water culture, bubbleponics, and bioponics.[7-9]

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Hydroponic systems in plant cultivation have several advantages over conventional systems, in that hydroponic systems can produce a larger quantity of plant yield than conventional systems. In addition, the land used for hydroponics is not only limited to open land but can also be used in closed places such as houses or garages. Therefore, this system can also be utilized by urban communities who want to grow crops but do not have enough space. Hydroponic systems are not weather dependent and are considered an environmentally friendly. Compared to conventional systems, hydroponic systems are more easily controlled. Therefore, the risk of crops being attacked by pests and diseases is smaller. Hydroponic systems are proven to be effective in improving crop yields in a short time with superior quality. The harvesting process is also easier and faster, the crops tend to be cleaner, the weight and size are more uniform so that the harvest has a better market share. [5,10]

Several studies have examined hydroponic systems. Suitable planting media are reported as being a very important variable in non-soil cropping techniques. Plant proponents and mediators of nutrient absorption have also been widely studied. Coconut or rockwool, as supporting materials of plants, are often used in hydroponic cultivation techniques. This is because coconut husk and rockwool provide adequate porosity which ensures nutrient capability and gas exchange at the root of the plant.[11]. The availability of plant nutrients in the system is strongly influenced by water. The differences between semi-continuous and continuous irrigation systems are considered to influence the effectiveness of nutrient absorption by plants. The differences in irrigation systems have consequences for plant growth and productivity, and the sustainability of the hydroponic system [12]. Several recent studies have also been conducted to examine the effect of different hydroponic composition media on yields, water use efficiency, and evapotranspiration of plants. The combination of conductivity differences and the pH of the media have also been reported to affect the greenness of leaves and plant height.[11-13]

Research on hydroponic plant cultivation has been conducted abroad. Hydroponic techniques in Indonesia are widely practiced but the reports of success rates (especially in vegetable crop yields) are not widely available. Research results from studies conducted abroad cannot be directly applied in Indonesia. Modification of nutrients and irrigation systems needs to be done to obtain the optimum growth and productivity of plants due to the specific environmental conditions. Therefore, this research is conducted to provide a new hydroponic design that can be used for future experiments regarding nutrition modification and irrigation systems in hydroponic plant cultivation in Indonesia.

EXPERIMENTAL DETAILS

This research was conducted in the greenhouse of the Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang City, Indonesia. The design was arranged based on several reference studies on hydroponic systems. The new design of the hydroponic system in this study is mainly a combination of the ebb and flow system, and the nutrient technique system which was described by Lee and Lee [14] as follows:

- The ebb and flow system is a system that automatically uses two different watering systems (flood and drain). The plants cultivated in this system are temporary and periodically flooded. The strength of this ebb and flow system is its capability to utilize various media for plant root growth. In addition, the water availability level is controlled by the circulation system which needs to be continuously monitored.
- The nutrient film technique is abbreviated as the NFT system. The NFT system not only provides a constant water and nutrient supply but also oxygen-rich conditions. The flow and water depth are controlled by the tray slope and the water pump power.

RESULT AND DISCUSSION

The hydroponic system in this study featured four polyvinyl chlorides (PVC) pipes, two water tanks, a water pump, and four valves. Figure 1 shows the system design plan.

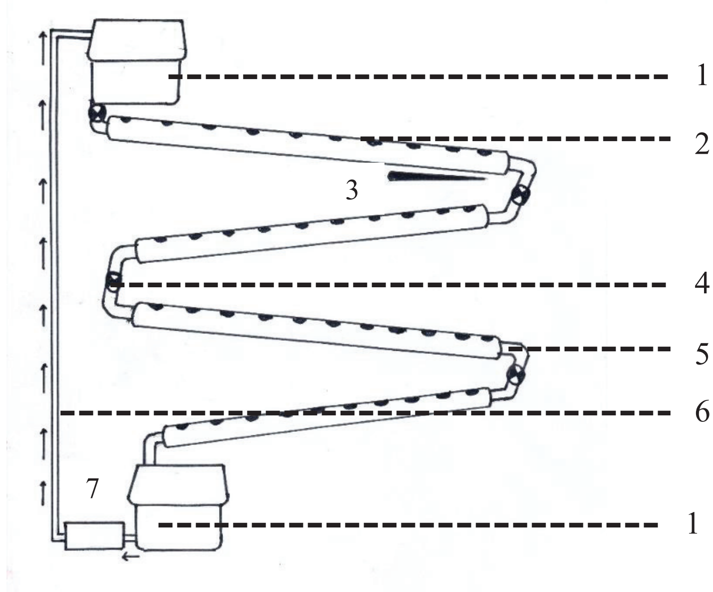

FIGURE 1. The design plan of Vertical hydroponic system with semi-continuous and continuous nutrient cycling (1) tank, (2) main pipe, (3) slope 4^o, (4) valve, (5) junction pipe, (6) small pipe, (7) water pump

The vertical hydroponic system was arranged with two water tanks, four main pipes with a 4^o slope, four valves, several junction pipes, a small pipe, and a pump. The materials and specifications of the hydroponic features are noted in **TABLE 1**.

TABLE 1. Specifications of the design of vertical hydroponic system

Attribute	Remark
The system	Vertical hydroponic system
The pipes	Polyvinyl chloride
Main pipe diameters	16 cm
Main pipe slope	4o
Water tank volume	80 L
The number of valves	4
The water pump	Unspecified

The hydroponic system mentioned above harbored four valves that intended to regulate the depth and water rate inside the main pipes. Since each valve connected to different main pipes, the water rate of each pipe could be individually regulated. In addition, the hydroponic system arrangement needed a skeleton, therefore light steel was used as a skeleton for this system (Figure 2).

FIGURE 2. Final construction of the hydroponic system. There is a valve addition at the end of the fourth main pipe

The final hydroponic system was constructed from two basic parts involving the skeleton and the pipeline system. The skeleton dimensions were 200 cm, 50 cm, and 150 cm for its length, width, and height, respectively. In addition, the final length of each main pipe was 197 cm. Each one was connected with the junction pipe.

FIGURE 3. The temporary test of vertical hydroponic system

Additional features were added. These consisted of an extended net pot and rockwool as the hydroponic media. The net pot was extended to be capable of cultivating plants with long roots. The diameter of the net pot was 10 cm while the total height of the extended net pot was 7 cm. The net pot and rockwool

The irrigation system was also tested. In semi-continuous irrigation treatment, nutrients could flow four to six times for each of ten minutes depending on plant need, while in a continuous nutrient system the nutrients could be streamed for twenty-four hours without stopping at a maximum flow rate of 13.7 L per second.

SUMMARY

The design of the hydroponic system involved a combination of several previous systems. The system could be used for a continuous irrigation system, 24 hours without stopping. The rate of irrigation of each main pipe could be independently adjusted.

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