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Comparation of Hydroponic System Design for Rural Communities in Indonesia

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ABSTRACT

The interest of the younger generation in Indonesian rural areas to become farmer generally decreases. The problem they face is the reduced agricultural land also due to lack of farming ability. Since the introduction of hydroponic system for rural region, many young farmers are motivated to become independent farmer. This study is intended to find a hydroponic system that is suitable for rural situations and conditions in Indonesia. This research examines various existing hydroponic systems with comparative and experimental methods to find the most suitable model. The results obtained show a variety of promising qualities. One hydroponic design with a perforated bulkhead system that produces nutritional water waves, shows superior plant growth results. This hydroponic design with the application of hydrotropism shows a positive correlation between the movement of water and the growth of roots and leaves. Hydroponic products with hydrotropism components as the findings of this study can be recommended to be developed in rural areas in Indonesia.

Keywords: Agriculture, Hydroponics, Hydrotropism, Product Design.

1. Introduction

Changes paradigm in the rural communities towards agricultural traditions in rural and forest village areas almost occur throughout Indonesia. Most of the young generation of rural area move to cities to become employees or trader. Only a small number live in the village to work as traditional farmer and breeder, as well as to maintain inherited land. The younger generation of village farmer who choose to work as farmers generally face the problem that the area of family farmland is getting smaller due to the distribution of inheritance rights. The availability of a small land area, low expenditure and financing capability, is a typical factor for young farmers who need to be considered in finding a solution.

This paper offers an agricultural model for young farmer in a hydroponic way. Hydroponics is the cultivation of plants by utilizing water with or without using aggregate and emphasizing the provision of nutrients for plants. In aggregate use, some growth media can be used as supporting plants and mediator of nutritional solution. Growth media can be made from coal, sponge, cocopeat, sand, expanded clay, rockwool, vermiculite, moss, wood powder, and fern stems (Roberto, 2003).

Hydroponic systems are often mentioned as solutions to problems that occur in conventional farming systems based on soil fertility. This system offers several advantages over land-based systems. When plants are removed from the ground, root tissue is often cut mechanically which results in tissue loss or damage. This is especially true for fine root structure such as lateral root and root hair. This causes soil-based plants to degenerate (Nga T. Nguyen, 2016).

Hydroponic system in plant cultivation have several advantages over conventional system. This system can produce a greater number of crop yields than conventional system. In addition, the land used for hydroponic is not only in open land but can also be used in closed places such as house or garage, and do not depend on the weather and considered environmentally friendly. Therefore, this system can also be used by urban communities who want to grow crops but do not have enough space. Compared to conventional systems, hydroponic systems are easier to control (Siswanto & Widoretno, 2017). Hydroponic systems have been widely studied, including the management of nurtrient in recirculating hydroponic culture (Bugbee, et all, 2004), the treatment with salicyl acid that decreases the effects of chilling injuri in maize plant (Janda, et.al, 1999), design and analysis of mixture systems in hydroponic plant nutrition (Schreven adn Cornel, 1993) and many more.

The trial of this hydroponic system for the village community is an important effort in understanding hydroponic science and technology whose echoes have reached the rural area. Apparently observing by comparing the quality of growing plants is a fun activity, because there are quite a lot of things about hydroponics that can be understood directly by the village community. Village farmer communities basically have the hope to improve their welfare through the use of hydroponic systems as a good alternative to replace conventional agricultural work methods and processes.

The aim of this this research to find out for the hydroponic system that is most suitable especially for the region the experiment took place and generally for Indonesian rural areas with limited farmland. As for the purpose of this study is to encourage young farmers in the rural area to utilize existing land with hydroponic model farming. With this farming system, it is expected that young farmers can improve their welfare by producing agricultural production by hydroponic system.

1.1 Hydroponic system

Hydroponic systems that are popular in Indonesia, consist of two types. First the hydroponic system without water pump and the second is those that use electric water pumps. Hydroponic systems without water pump among others: (1) a water-culture system or floating raft, this system utilizes platform made of styrofoam, cork or other planting media that floats on the water. The platform containing the netpot line is placed floating above the nutrient pool so that the roots of the plant can immediately absorb nutrients. (2) The wick (axis) system is a system that connects a water bath containing a nutrient solution with the planting medium through the capillary axis. This capillary axis absorbs nutrient water for root growth. (3) Fertilization System (fertilizer and drip irrigation system), this system uses drip irrigation or drip irrigation systems where plants are doused with nutritional water droplets. If using unidirectional irrigation such as a shower, this system does not require a water pump.

The secod is hydroponic systems that require nutrient water circulation, generally use water pumps with electrical energy, namely: (1) Nutrient Film Technique (NFT) where the roots of plants are placed on the shallow circulating nutrient water layer. The roots of the plant absorb nutrients and oxygen from nutrient water that flows continuously using a pump. (2) Ebb & Flow system (tide and low tide) is through pumping a reservoir containing nutrient liquid to wet the roots during tide, and returning the remaining nutrients to the reservoir at low tide. (3) Deep Flow Technique System (DFT) system that is putting plant roots in the nutrient circulation layer at a depth of 4 cm to 6 cm. Aquaponics is a hydroponic system that uses fish ponds as a nutrient bath circulated to the planting medium (Maucieri, 2017)

Basically, the research that compares among hydroponic systems, no one has done it directly. However, there are several studies that carry out comparative studies between hydroponic systems indirectly or limited to the comparison of two hydroponic systems only. Some comparative studies relevant to this research are: a statement that there are hundreds of variations in hydroponic systems, but all hydroponic methods are variations and combinations of six basic types, namely: Wick, Deep

Water Culture (DWC), EBB and Flow (Flood & Drain), Drip (recovery or non-recovery), Nutrient Film Technique (NFT), and Aeroponics (Green Vibrant, 2018), (Hydroponic University, 2008). This type of wick (axis) hydroponic technology is the development of a water culture system, the simplest hydroponic system for beginners In a comparative study with conventional systems with measurements of plant growth rates and number of leaves, it shows that the wick hydroponic system is superior.

The axis system is the simplest of all types of hydroponic systems. That's because traditionally it has no moving parts, so it doesn't use any pump or electricity. However, the axis is the connecting part between the pot plant and the food solution in the existing reservoir. Because there is no need for electricity to work, it is also very useful in some places where electricity cannot be used, or is not reliable. The axis system is a type of system that is easy to build when you first learn hydroponics. This type of hydroponic system is also often used by teachers in classrooms as an experiment for children. In the axis system the plant is cultivated on the substrate. (El-Kazzaz & El-Kazzaz, 2017)

Comparative study that has been done by Maucieri (2017) used NFT hydroponic systems with aquaponics, in an experiment to optimize the growing function of mustard plants (*Brassica rapa subsp. Chinensis*), showed a better results than aquaponics. When compared with all existing hydroponic systems, the NFT and Wick systems are examples of the simplest, easiest to make, and minimal decomposition of plant hydroponic system technology. In the comparison between the NFT system and the wick on the measurement of plant growth rates, the NFT system showed different growth variations, which was caused by the possibility of uneven nutrient absorption, while the wick system showed good results.

Helmy (Helmy, et al, 2016) has conducted an experiment with NFT hydroponic systems can be relied on for large-scale production, because the nutrient supply in this system must always flow so that all the netpot in the circuit gets enough nutrition. Even this NFT hydroponic system must be arranged in a systematic configuration so that nutrients can be circulated properly. The disadvantages of this NFT hydroponic system include: (1) the availability and maintenance of hydroponic devices is rather difficult and (2) relatively larger initial capital. Very different from a wick system that can use simple equipment. Hydroponic system for cultivation of plants that very popular today in Indonesia is the Nutrient Film Technique (NFT).

2. Material and methods

2.1 Material

The location of study is in Cibeureum Village, Sukamantri District, Ciamis Regency, West Java Province, Indonesia. The place chosen because in 2006, this region launched as an agribusiness and agrotourism area by the Minister of Agriculture of the Republic of Indonesia. The government formed the Self-Supporting Agriculture and Rural Training Center) (P4S) Karang Sari, with main task is to develop the potential agricultural in the region. In this village several experiments were made with various hydroponic models: hydroponic systems without electric pumps as in wick (axis), drip (drops), water-culture systems, aeroponics (fog), and hydroponic systems with electric water pumps, such as: NFT, Fertigation and Ebb & Flow systems.

In participatory activities with a team of budding farmers, this experiment was limited to parameters that could be carried out through simple visual observations and measurements. Measurements did not include of light factors, environmental temperature, nutrient, water temperature and nutrient consumption.

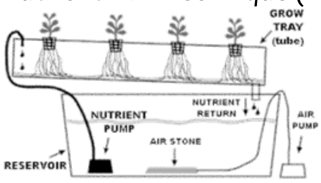
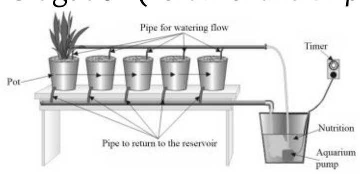
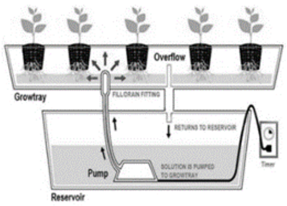
2.2 Methods

Based on the existence of this hydroponic system, this research used comparative and experimental study among existing hydroponic system. Testing and trial efforts are needed to find or choose which system is most suitable for the situation and condition of the village environment. The trial process of these hydroponic systems is carried out in a rural environment by involving beginner farmer and productive conventional farmer. To obtain an actual picture of a hydroponic system that is relevant to the rural environment, a comparative method is needed among system with a pattern of observation of the rate of plant growth. The comparative method of three different hydroponic systems is carried out using a trial method or maintenance rate for 4 (four) weeks. The process of observing the growth rate of green mustard (*Brassica rapa subsp. Chinensis*) is carried out in a simple green house made of UV plastic sheets, which made specifically in three different places. This observation was carried out by three farmer groups.

3. Result

Hydroponic system trials without electric pump equipment get the most response, so that it can be done by novice farmer directly. The concept of water culture, wick and drip is done using simple equipment available in the village. Whereas those that use electric pumps, timer and other equipment, are carried out in the form of collaborative experiment with farmer to get an overview of effectiveness and efficiency. Thus this comparative study uses only hydroponic systems that use electric pumps, shown in table 1 below:

Table 1: Comparative schemes and working methods of three hydroponic systems

Hydroponic scheme	Systematic work
Nutrient Film Technique (NFT)  (*paktanihydrofarmshop.blogspot.com*)	1. The nutrient water pump drains water from the nutrient water tub to the growing media pipe, after passing through the root line, back to the water bath supplied by O2 from the wind pump.
Fertigation (*Fertilizer and Drip Irigation System*)  (*paktanihydrofarmshop.blogspot.com*)	2. The water pump draws nutrients from the reservoir, flows into the drip pipe that water the plants. Nutrient flow is set by timer.
Ebb & Flow System  (*paktanihydrofarmshop.blogspot.com*)	3. The water pump that is in a nutrient bath sends nutritional water to the growth medium or vessel until it is full enough, then within a certain duration the nutrient shrinks slowly back to the water bath like a tidal cycle

The comparative study for the three hydroponic systems was carried out to obtain an overview of the system that provides the most optimal results, so that the younger generation farmers can believe the potential of hydroponic science and technology as the best choice for farming in the countryside today. The results obtained are the basis for recommending the best selection of hydroponic systems. If the results obtained show no significant quality differences, then no recommendations are needed for novice hydroponic farmers.

The process of collaboration with budding farmer in the hydroponic system experiment was carried out by three groups for three hydroponic systems that had been produced by hydroponic farm equipment manufacturers, with locations in the yard of the house available for PLN electricity grid. Observations are carried out for one month, with the process of recording data every week. Plant growth data measured every week include plant growth rate, leaf growth and root length growth. Measurements every week are intended so that the research team together with farmers can observe carefully and diligently on the subject of the research, especially if there is abnormal or dead plant growth by another cause.

In the trial of the three hydroponic systems, it was agreed to only use the media of green mustard vegetable (caisin), which was also planted by village farmers with conventional farming systems. It can also be used as a comparison material for plant quality, between hydroponic systems and conventional agriculture. The final measurement of this process was carried out on the fourth week of mustard plants that grew healthy as much as 12 netpots each. Manually measured parameters are: (a) plant height, (b) number of leaves and (c) root length.

3.1 Result-1 nutrient film technique system (NFT)

The measurement results of 12 mustard plants in the netpot on the NFT system, give an average value as in table 2 below:

Table 2: Data from the measurement of the NFT system

Nutrient Film Technique (NFT) System						
Team	(a)	Plant height	(b)	Numberof leaves	(c)	Root length
A		24.6		9.2		27.3
B		24.5		9.3		27.2
C		24.6		9.8		29.2

For the NFT system, the highest average value of the plant measured from the base to the tip of the leaf is 24.56 cm, the number of leaves calculated includes large leaves and small leaves an average of 9.4 strands with an average root length of 27.2 cm.

3.2 Result-2 fertigation system (fertilization and irigation)

In the fertigation system (fertilizer and drip irrigation system), there is a difference slightly smaller than the NFT system, as illustrated in table 3:

Table 3: Data from the measurement of the fertigaion system

Fertigation (fertilizer & Drip Irrigation) System						
Team	(d)	Plant height	(e)	Number of leaves	(f)	root length
A		24.2		10.2		24.3
B		23.7		9.4		26.2
C		23.9		9.8		25.2

For the fertigation system, the average plant height was 23.9 cm, the average number of leaves was 9.8 strands with an average root length of 25.2 cm.

3.3 Result-3 ebb & flow system (tidal)

On Ebb & Flow system (tidal) using a timer that regulates the tide process in a duration of 15 minutes until the nutrient water reaches 4-6 cm, and undergoes a root soaking process and absorption of nutrients during the tide process takes place. The process of receding takes place quickly because it uses gravity, where after the immersion and absorption process, the nutrient water immediately returns to the reservoir which is in the lower position of the planting medium, as can be seen at table 3 below:

Table 3: Data from measurement of Ebb & Flow System

Sistem Ebb & Flow						
Team	(g)	Plant height	(h)	Numberof leaves	(i)	root length
A		24.2		9.2		27.3
B		22.7		9.3		25.2
C		24.4		9.3		26.4

For Ebb & Flow system, the average plant height was 23.7 cm, the average number of leaves was 9.2 strands with an average root length of 26.3 cm.

The hydroponic system trial process, which was carried out with community participation, yielded interesting results, where almost all three systems that were tested could provide sufficiently balanced data, so that farmer could choose according to their individual taste. As a result of this comparison, the NFT system provides better result than other systems, so that the NFT system can be developed for use in rural areas. The trial of the NFT system and Fertigation, went quite smoothly. This experiment produces data that is quite accurate when compared with the results of other studies on the growth prospects of mustard plants through hydroponic systems.

In the Ebb & Flow system experiment process, there were several errors caused by the lack of validity of the immersion duration or the tide time that exceeded the duration of 15 minutes and less than 15 minutes. The ebb & flow system is considered by the village community as a hydroponic system that is less practical, because it is in desperate need of continuous monitoring. In order for the tidal interval to be stable, it is recommended that this system use an automatic timer with a microcontroller (Delya, et al., 2014).

4. Discussion

Plant growth experiments with measurements on high quality grown, number of leaves and root length, basically related to product design analysis which includes: aspects of shape, construction, component configuration, circulation, implementation of water pump functions, electricity grid, drainage pipe installation, and various things related to the application of hydroponic science and technology. The application of a hyderoponic system to the production model of large-scale vegetable crops, the yield of the crop is strongly influenced by design factors, environmental factors and business management factors. The dimensions and and configuration of different hydroponic system components can produce different growth qualities. In the experiment on the quality of growing plants with different heights and slope of the direction of the pipe in the NFT system it turned out to produce different growth qualities. The principle of the influence of water motion on hydroponic vessels, both caused by the slope of the pipe factor and the high and low configuration of the pipe circulation configuration, turned out to be very influential on the quality of growing a plant. This is similar to the principle of swift current which makes fish move continuously so that it grows larger than fish in conventional ponds. Basically all plants have the ability of irritability, which is sensitivity to stimuli and respond to stimuli. This irritability factor in particular causes esionomic motion in the form of a pattern of motion that is influenced by external stimuli. The esionom movement which is affected by the motion of water which stimulates the growth of roots or other parts of plants is called hydrotropism. The dynamic pattern of water motion that stimulates root growth in hydroponic system is called hydroponic hydrotropism system, which carries the principle of tropism for use in hydroponic systems. Hydroponic system motion patterns in general are linear motion called normal motion, whose water flow depends on the pump speed and the slope of the pipe, as shown in figure 1 visualization:

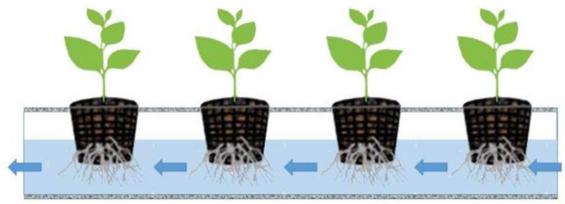


Fig. 1: Linear current pattern in hydroponic pipes

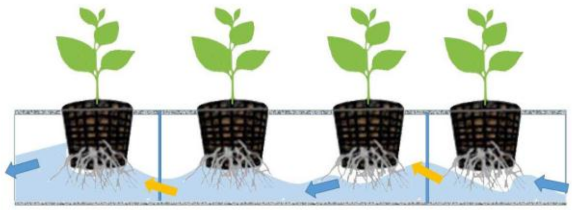


Fig. 2: The pattern of the current wave of hydrotropism

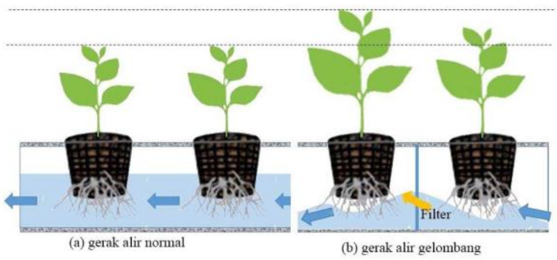


Fig. 3: Comparison of normal currents and wave currents to quality grows.

Based on the principle of hydrotropism, the nutrient flow is made corrugated by using a perforation filter on several pipelines, this perforation component fragment can be adjusted for various expected water motion patterns. The general motion of the wave current is described as in figure 2:

The mechanism of this hydrotropism movement has an impact on improving the quality of growth, such as visualization in the following figure 3:

By comparing the results of the NFT system experiment with this new system, there are growing quality results that show better hydroponic systems. As shown in table 4:

Table 4: Data from the hydrotropism system measurements

Hydrotropism System			
Team	(j) Plant height	(k) Numberof leaves	(l) root length
A	25.2	10.2	27.3
B	25.7	10.3	27.2
C	25.4	10.3	27.4

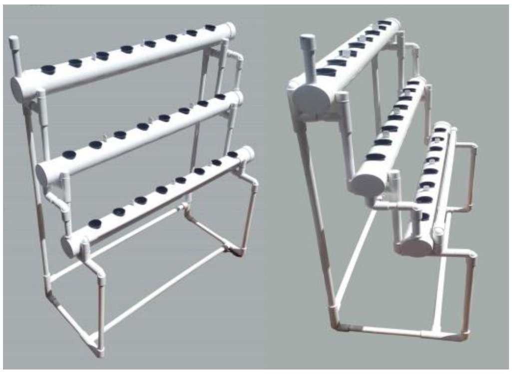


Fig. 4: Hydrotropism hydroponic system design

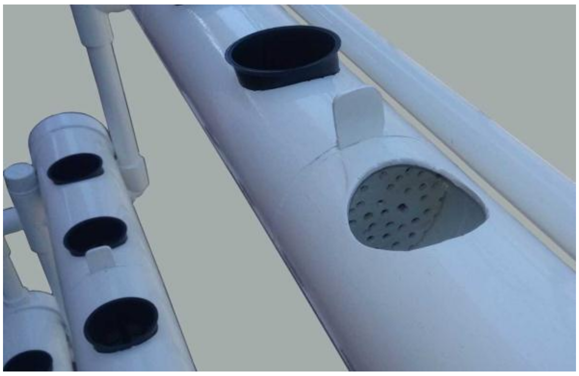


Fig. 5: Details of perforation on hydroponic pipe sections

Based on this data, the product design concept of the hydrotropism system can be introduced to improve the quality of plant growth. Hydrotropism system design description as shown in Figure 4.

Details of the perforation system or perforation filter on the pipe section that cause water ripples or waves as shown in figure 5, this system produces good waves if supported by sufficient pump speed.

5. Conclusion

The comparative process of several hydroponic systems for use in rural areas, proves that NFT, Ebb & Flow and Fertigation hydroponic systems can be widely used in rural areas. The hydroponic concept which was originally intended for plant enthusiasts in big cities, turned out to be relevant also to be developed in the village area, which is currently almost experiencing problems of limited land due to the change of function and the unsustainability of the livelihood work of traditional farmers in the village.

The comparison of hydroponic systems is carried out to provide an overview of the prospects of hydroponic systems to increase the productivity of vegetable farmers in the countryside. Basically, all of these hydroponic systems function very well for hydroponic development in the village, both those without electricity and those that require water pumps and other equipment. In the scientific discipline of Product Design (Industrial Design), the trial process or experiment involving community participation is an opportunity to create a new hydroponic system that is more relevant to the needs of the village community.

This study can ultimately address the new hydroponic system, which comes from the potential and relevance of science and technology. If the design of this product is developed for further research related to the prospect of optimizing the quality of plant growth, a more detailed and well-measured observation variable is needed.

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