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Fabrication of indoor vertical farming for urban area

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ABSTRACT

Previously, indoor vertical cultivation was made from source using complex system methods called hydroponics, aquaponics and aeroponics. The project system is different when compared to fertigation and traditional cultivation. The use of large spaces and the frequent use of pesticides in previous systems are major problems in agriculture today. So, this vertical farming system can avoid such things. The objective of this project is to design and fabricate indoor vertical farming in small scale, an electronic circuit to control automation watering, less energy usage and measure the root growth rate plants comparison with traditional farming. However, Controlled Environmental Agricultural Technology (CEA) is used in vertical farming to control temperature, light, humidity and water for crops. By using sensors, this method will grow automatically and is good for crops. But in this indoor vertical farming, the control that has been applied is watering the plants at the set time, lighting for indoor farming and sensors to know the water level in the water container. The data collection and results obtained from this project are shown by the graph that the use of this indoor vertical farming is better than traditional farming, which has been compared by measuring the root growth response on seedlings in vertical indoor farming with traditional farming. Finally, the project can meet the needs of consumers to start growing vegetables, fruits or food indoors.

Keywords: Vertical farming, urban area, indoor

1. INTRODUCTION

Everywhere on the world, people understand that farming is something they must do regardless of where they are. Farming is very important for living things in this world. Recently, the building and technology rise quickly in every country. Beyond those challenges, a growing city population is also increasing the demand for food sources that are unchanging, available and healthy. Future mega cities are more regionally or culturally diverse, particularly larger, poorer and less advanced than existing urban populations [1-8]. That may cause losing the land and the soil to planting and farming to produces the food (oxygen also) and for all living thing. Hence, the idea of indoor vertical farming has emerged. Indoor vertical farming, mainly is an alternative method and technology for gardener for planting in their building or houses with a minimum place. Vertical farming as the name of, vertical means straight line at the right angles to a horizontal plane, in direction or having an alignment such that the top is directly above the bottom. Usually, this farming method plant in straight and obliquely (and horizontal). It's had a multiple level to plant the crop and produce some food [9-16].

Controlled Environment Agriculture (CEA) technology is using in vertical farming to control the temperature, light, moisture and water for the plant. Using a sensor, this manner will progress automatically and fine. A plant desperately needs a good light, water, and nutrient as possible to produce a healthy food. Hence, CEA is important in indoor vertical farming. Previously, fast cities

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and development in all nation growth has an impact on agriculture, since farmland was destroyed to create a new construction and residential area. As mentioned in research background, this thing happens because the land is already taken by another used, such as a big building and created a new city. Because of that matter make no places for agriculture. Indoor vertical farming gives gardeners with limited horizontal space and gardeners wanting to optimize their yields the smartest option. The current situation of traditional farming is always using a huge range of area to plant. Traditional farming usually produces a food with a large amount in a year with the machine and another technology. It may have more cost and more land uses. In the next 20 or 40 years we cannot hope that have the land to do the farming [17-24]. Vertical farming is the best solution to handle this situation because this manner gives a chance to gardener to do their work only in houses and from the top on building. No more issues for do farming in future and to plant in or on a skyscraper because vertical farming can fit in building or houses or compact places. Earlier on, the type plant was used in vertical farming small plant such as tomatoes, carrot, lettuce, radish, cucumber and peas. It is because primarily suitable for walls, fencing, balconies and increased growth densities in small yards. They do not grow high and may be utilized successfully. Vertical farming not suitable for the big tree like mango, coconut or others. The small crops can make easier to plant in narrow and compact place with vertical way with the level. Formerly, traditional always used a lot of pesticide in farm to protect their crop. Chemical pesticide is very dangerous for plant, and also for human. It may cause human can be poisoned and affected by a dangerous disease such as a cancer. Maybe we can see this dangerous chemical on our sight, from the experiment it's already prove chemical is not good for our healthy. It is also will decreases the nutrient of plant and that crop is not healthy to eat anymore. The method of vertical indoor agriculture might be avoided.

The usage of chemical pesticide can be dangerous for the people. It possibly avoided when practice indoor vertical farming method. From managed circumstances of production, it will minimize the need of chemical pesticides. Ahead of time, everybody didn't know about indoor vertical farming because it's not famous in our community. The people are not exposed to this yet. They already accustomed by the traditional faming method. This matter needs to be revealed from now on to introduce how well this indoor vertical farming for people in future. Do a promotion and encourage vertical farming is the best way to introduce this to the people. Indoor vertical farming will be large- scale production of crops the benefits of this form of agriculture may be explored further. The main problem statement in this project is the traditional farming always using a large area to farm and it may have more cost and more land uses. Next, usually in farming. Using a pesticide is common in world nowadays. Vertical farming is created to avoid using a pesticide to our food because chemical pesticide is very dangerous for plant, also for human and animals. In this study, there are two objectives to be achieved which are to design and fabricate small scale the indoor vertical farming frame which is suitable for home usage. Apart from that, it is also to design and fabricate an electronic circuit for the indoor vertical farm soto achieve monitoring and control automation watering and less energy usage. Lastly, the final objective is to investigate and measure the root growth rate plants and comparison with traditional farming.

2. RESEARCH METHODOLOGY

Generally, the project of making an indoor vertical farming system will use in small-scale that suitable to fit in a house (Figure 1). The materials and tools should be suitable and always clean to places inside a houses (building). There are various studies and improvement on making indoor vertical farming system. Most of the developments are making small that want to be small-scale that suitable to fit in a house or building. The appropriate way for solving the problems is to introduce the tools and components in indoor vertical farming. This framework was specialized with the sensor type. The components and materials of the device were selected to fulfil the users' expectations without any expertise required on handling this.

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Figure 1. Vertical Farm Framework Final Design Using Solidwork 2016

From the flowchart of an indoor vertical farming systems (Figure 2), firstly switch button on consists the sensor for water levelling, switch for lighting, and timer plug for water pump. The sensors were controlled using an Arduino microcontroller. The timer plug that already set to 15 minutes in 2 hours per day. The Arduino microcontroller will extract the signal and coded information required from the water level and switch on the light, pump to do their work. Next, water pump with 12V began to absorb water in water container when switched on, then direct flow water to the top of tower and the rest of water that do not touch the roots of the plant flow back to the water container. The light will provide the light and can be set up to different color (red: suitable for plants) [25-32]. In this case, the gravity will take in, which water going down through the plants in a minute that already set and the pump will rotate the work recently when it's started. With the respect to times, the water pump will stop for 2 hours.

Then, the root growth respond of the water spinach was calculated, and it was compared in terms of indoor vertical farming and traditional farming. Software used in this indoor vertical farming systems is to design and the frame of the vertical farming finalize design to facilitate an overview of the framework for carrying out this project and to programming the code for processes in Arduino system. Solidwork 2016 is using to design an Indoor vertical farming frame. As mention early, the design must be sketch part by part with the correct dimension in real. Firstly, take the measure of the pipe tower, water container, and others before start sketch in Solidwork. Then, after done all part of the vertical farm frame, assemble them use a mate feature one by one. Lastly, after assemble, we can select the new feature for a model view in drawing file (Figure 3). Arduino develops, makes, and maintains electronic devices and software that enables people worldwide to readily access innovative technologies that interaction with the real world. Our products are easy, simple, and powerful, capable of meeting the needs of customers ranging from students to makers to professional developers.

It starts by sowing 20 spinach seedlings, in rockwool and 20 seeds into the soil (peat moss). The seedlings, watered with regular water 4 times a day (morning, noon, evening, and night) evenly (Figure 4). After 10 days the seeds germinate, the seeds in the growing rockwool are transplanting into the indoor vertical farming system, while another 20 seeds planted in the ground (traditional farm) are left there for comparison purposes between indoor vertical farming and traditional farming.

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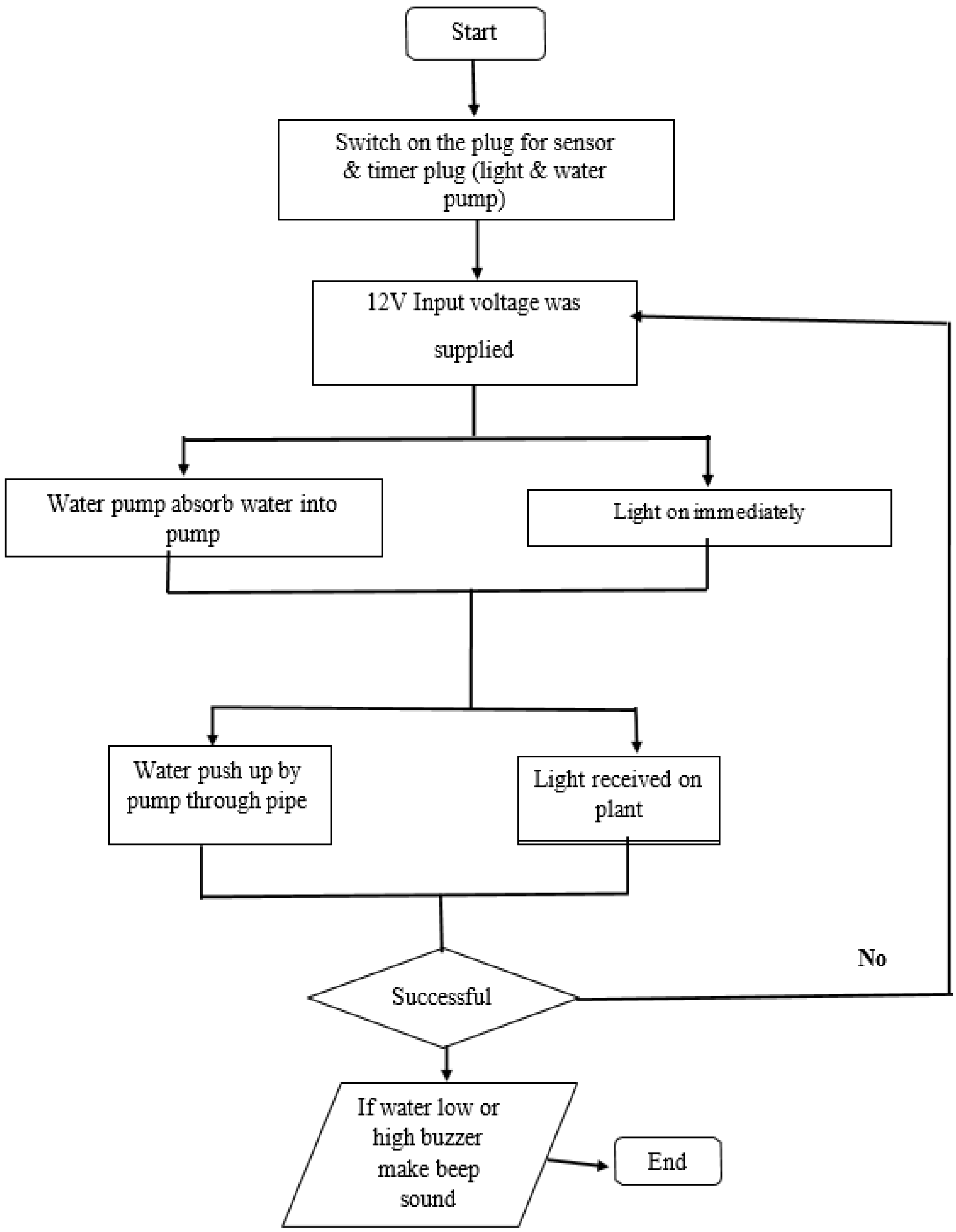

Figure 2. Flowchart of the Indoor Vertical Farm System

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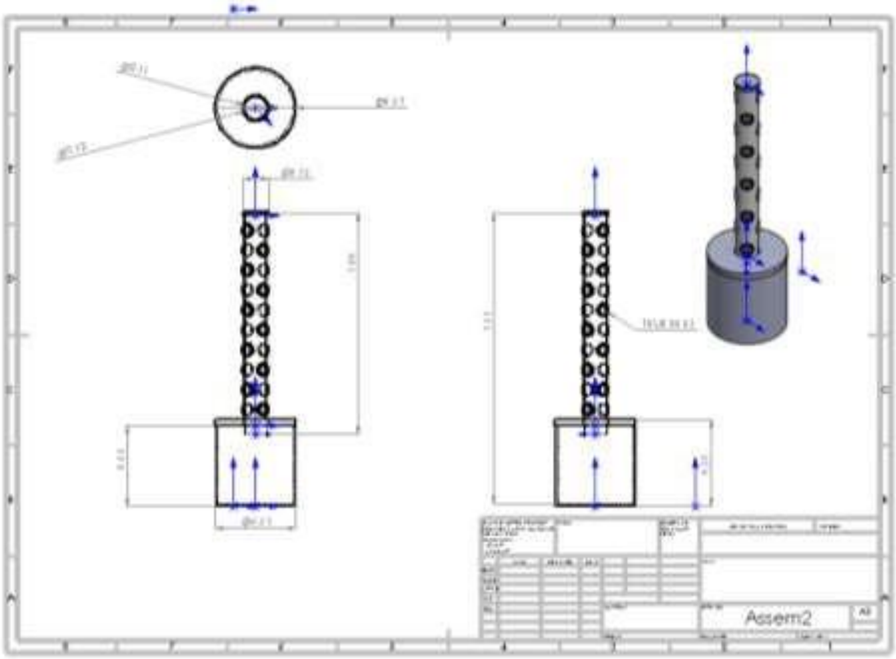

Figure 3. Model view drawing of Indoor Vertical Farming Frame

Figure 4. Seedling water spinach in rockwool and in peat moss

After that, start building a framework for indoor vertical farming to finalize the design. At the beginning, punch a hole in the top of the water container lid that is suitable to insert the pipe tower into it. Make sure the hole is right on the centre of the water container cover to avoid instability of the pipe tower to stand. Connect the pipe PVC 2.54 cm into the outlet water pump straight in the middle of the pipe tower. After finishing, punch a hole in the upper side of the water container to insert the jumper wires (Arduino) that are connected to the water level sensor in the water container. The hole on the side of the water container also serves to remove the power wires of the water pump located in the centre of the water container.

Next, stick a stainless-steel plate (round) on the bottom of the water container which aims to stabilize the position so as not to move roughly in the water container. For the Arduino microcontroller, firstly punch a hole in the circuit box for the purpose of inserting 5-volt (power) wires and also jumper wires from the water level sensor. Then, connect the jumper wires from

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the water level sensor with the Arduino uno using male-to-female types. This water level sensor uses 5 volts (+), so connect to the Arduino output 5 volts. Then, connect it to the ground Arduino from the water level sensors (-).

After that, connect the wires from the water level sensor symbol (s) to the Arduino input (A5) for signal detect water level condition in water container. Then, insert the LCD display connector into the Bret board to do some connection with the Arduino. Connect the power and ground from the Arduino to the LCD display power and ground to on the LCD display. After that, connector power from Arduino which is 5, 4, 3 and 2 to LCD display for trigger the display. For buzzer, connect from the Arduino output (10) to the input buzzer and connect the ground to the ground Arduino.

When the data from detect from water level sensor and straight give signal to LCD display that shown low, medium or high. From that, the buzzer will function whenever water level low or high. Then, for the water level sensor, create a water protector (plastic) to prevent the connection of the water level sensor with the jumper wires not exposed to water and stick the water level sensor with a cable tie/tape on the inside of the water container. After that, do a water level sensor test by carefully inserting water into the water container. At the same time, turn on the Arduino switch to run the sensor process.

After which has been programmed where if the water is low and quality, the buzzer will sound because the water is still low and need to stop putting water into the water container when the water exceeds the high level (LCD display will be shown and buzzer beeper). The test is continued by setting the parameters of the position of the water level in the water container when high, medium and low. Repeat this test until you get the appropriate result. When done, put water and AB fertilizer into a water container with a medium level.

After 10 days the seeds germinate, the seeds in the growing rockwool are transplanting into the indoor vertical farming system, while another 20 seeds planted in the ground (traditional farm) are left there for comparison purposes (Figure 5). The place for traditional farming is when the plants are placed in an aluminium tray and placed in an area that is exposed to sunlight (as is usually done). Watering and fertilizer for traditional farming is carried out manually which is watered 4 times a day at 7am, 1pm, 7pm and 1am with a mixture of water with AB fertilizer that has been mixed. In addition, in indoor vertical farming systems, as understood, watering, fertilizer and lighting are controlled, unlike traditional faming.

Once the spinach tree buds are placed into the hole of the tower pipe, a switch is installed. The first switch is for lighting. Second, the Arduino switch is for the purpose of knowing the water level in the water container and the buzzer will give a signal when the water exceeds the quality level and if the water is at a low level. When adding water, also add AB fertilizer that has been dissolved into the water container up to medium level.

After that, set the analog timer plug on every 2 hours the water pump is on for 15 minutes to water the water spinach trees in vertical farming. When finished, the pump will work for running water to each tree and lastly make sure the vertical farming position is in the affected area with the fluorescent lights that have been installed. Record root growth respond data every week in a month between the same 3 water spinach in indoor vertical farming and also in traditional farming to make a comparison between the 2 types of farming.

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Figure 5. Transplanting water spinach progress into pipe tower

3. RESULTS AND DISCUSSION

Indoor vertical farming system runs for a month and the data has been recorded during that time, that is taken once a week (4 times) root growth rate respond water spinach from both types of farming, indoor vertical farming and traditional farming. So, to coordinate and explain the comparison between these two types of agriculture is based on the roots of each of the 3 same samples of water spinach have been taken. root growth data records can be seen in both tables below. The difference samples of water spinach plant which are sample 1, sample 2 and sample 3 to get the average root growth rate respond. The 3 samples were marked with a position, which should be taken data on a weekly basis within a month. This table data and graph will show the measurement of the root by each sample, average, standard deviation and standard error of the water spinach in indoor vertical farming system (Table 1).

The samples were marked with a position on pipe tower (top of pipe tower), which should be taken data on a weekly basis within a month. This is done to avoid the occurrence of switching to taking water spinach during the weekly data collection process. Here also must be sure to do the work carefully so that the root is not damaged, because the root is for measurement and comparison in this project. This measurement is taken after the transplanted process after 10 days sown outside indoor vertical farming and wait for a week to get the first week measurement.

Table 1. Indoor vertical farming system for growth rate respond data

Water spinach sample	Growth Rate Respond (mm)			
	Week 1	Week 2	Week 3	Week 4
Sample 1	70	79	80	114
Sample 2	70	76	79	100
Sample 3	63	74	77	82
Average	67	76	78	98
Std. Deviation	4	2	1	16
Std. Error	2.3	1.4	0.8	9.2

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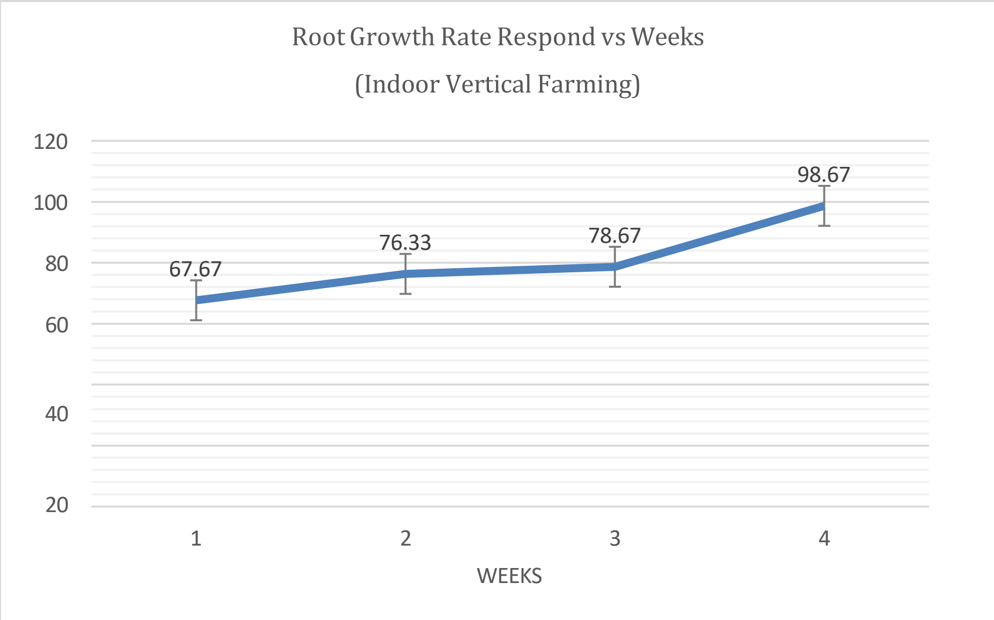

Figure 6. Graph average growth rate responds water spinach (indoor vertical farming) against weeks

In the line graph (Figure 6) of average growth rate respond in indoor vertical farming against this period (week) can see in the first week, the average root size for samples 1, 2 and 3 showed 67.67 mm. In the second week, the average reading increased to 76.33 mm, the third week was 78.67 mm and the end of the fourth week was 98.67 mm. The uptrend is shown in this graph nicely. Here shows from the first week to the second week the increase is as much as 8.77 mm. And in the second week to the third week it only increased by 2.34 mm.

Then, in the third week to the last week (a month) showed an increase of 20 mm. If you can look at the data, it can be seen that the upward trend is always up but not evenly like the second week to the third week which went up only by 2.34 mm. This may be due to factors from water and fertilizer not touching the roots evenly or due to lack of lighting factors on water spinach. If you look at the third week to the last week, the average root elongation is seen to increase dramatically. This may be due to; water spinach already feels appropriate in this indoor vertical faming system and gets food for adequate growth. In this type of traditional farming, the differences of water spinach plant samples are also taken, namely sample 1, sample 2 and sample 3 to obtain the average growth rate of the moving roots. 3 samples were marked with a position, which should be taken data every week for a period of a month in an aluminium tray. Water spinach in the aluminium tray also have as many as 20 water spinach as well as in the indoor vertical farming system.

The table (Table 2) and graph data (Figure 7) below will show the root measurements by each sample, average, standard deviation and standard error of water spinach in traditional farming type. Similar to vertical farming, 3 samples were marked with positions, which had to be taken data every week for a period of a month in an aluminium tray. This is done to avoid switching to water spinach intake during the weekly data collection process. Here also must be sure to do the work carefully so that the roots are not damaged, because the roots are for measurement and comparisons in this project. This measurement is taken after the sowing process after 10 days of sowing in and wait for a week to get the measurement of the first week for the same time as the data collected on the vertical farming sample.

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Table 2. Traditional farming system for growth rate respond data

Water Spinach Sample	Growth Rate Respond (mm)			
	Week 1 (10/1/2022)	Week 2 (17/1/2022)	Week 3 (24/1/2022)	Week 4 (31/1/2022)
Sample 1	60	78	90	100
Sample 2	55	64	80	90
Sample 3	40	58	62	80
Average	51	66	77	90
Std. Deviation	10	10	14	10
Std. Error	6.01	5.93	8.19	5.77

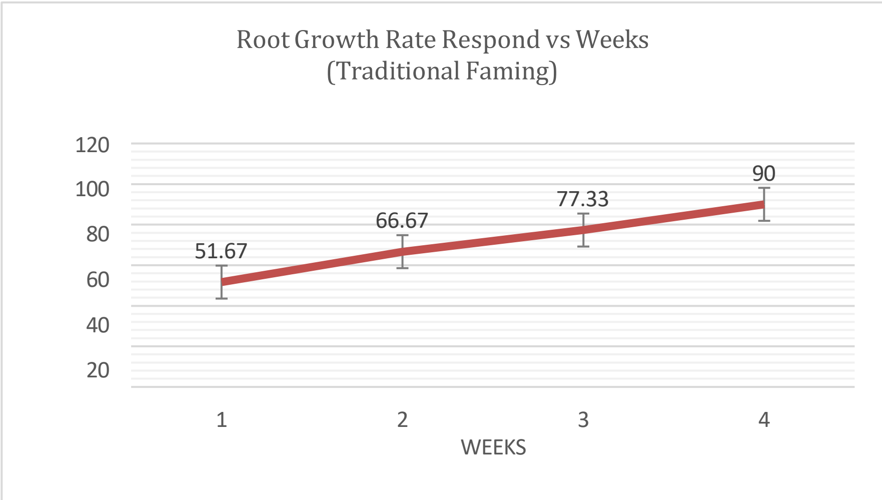

Figure 7. Graph average growth rate respond water spinach (traditional farming) against weeks

According to the traditional farming line graph of the average growth rate vs time (weeks), on week 1, the average root size for samples 1, 2, and 3 was 51.67 mm. The average reading grew to 66.67 mm in the second week, 77.33 mm in the third week, and 90 mm at the fourth week. This graph shows the rising tendency in a consistent manner. As you can see, the growth from the first to the second week is as high as 15 mm. That's all that happened in the second and third weeks: an additional 10.66 mm. In a month, there was a rise of 12.67 mm. Traditional farming's root size grew by 15 mm from week one to week two and only 12 mm from week three to week four; this tendency is evident in the statistics if we look at the data. Like the second week to the third week which only increased by 10.66 mm and the lowest elongation for the roots in this traditional farming.

The traditional farming that uses natural lighting from sun that is on the near room window, but still indoor. That factor also affects traditional farming to grow less effectively. In addition, other factors are due to water and fertilizer not in contact with the roots adequately on water spinach which this traditional farming uses human energy to water spinach every day for a month manually. Other factors may also be due to the fact that watering work carried out by humans makes the water is not enough and uneven to the roots of the plant. Compared to in a time-controlled vertical farming system for watering plants every 2 hours for 15 minutes in daily (12 times a day). Based on the graph of growth rate respond against the week between the types of farming that have been tested, namely indoor vertical farming with traditional farming, shows

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the growth rate of plant water spinach in indoor vertical farming system is very encouraging. If you look at the lines on the graph, the average increase in water spinach roots in indoor vertical farming is higher than traditional farming.

Here it has been shown that, the use of indoor vertical farming is proven effective from traditional farming (Figure 8). On the other hand, if you look at the third week of the increase in traditional farming with indoor vertical farming seems to be the same, but the plant in the indoor vertical farming system is higher. As described earlier, the third week in vertical farming showed a very low result of increase or elongation of roots from the second week and the last week, possibly due to erosion that occurred during the indoor vertical farming process was running at that time.

However, the final result obtained on indoor vertical farming is very satisfactory from traditional farming, which is seen last week on indoor vertical farming increased dramatically up to 20 mm in a week. Based on observation, using indoor vertical farming for indoor planting is better than traditional farming. As previously studied in this project, agriculture based on hydroponics, i.e. indoor vertical farming, is better than traditional farming. Since crops in vertical farms are grown under a controlled environment, they are safe from extreme weather events such as drought, hail and floods. Here it can be explained that traditional farming is usually open and exposed to unpredictable weather conditions in Malaysia compared to indoor vertical farming which has been fully controlled for the process of plant growth.

Moreover, in this indoor vertical farming growing techniques used about 70% less water than traditional farming (Arshad et al., 2018). Traditional farming carried out in this project is left exposed to sunlight, near the room window, which is still indoor (purpose for comparison) but the quality obtained and shown by the data is not satisfactory.

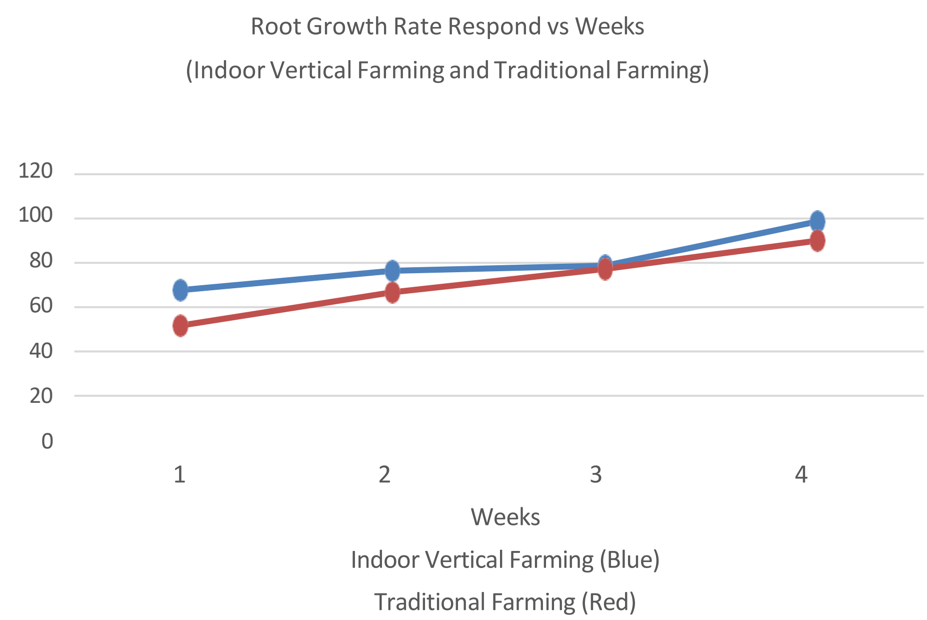

Figure 8. Graph average growth rate responds water spinach against weeks between indoor vertical farming and traditional farming

4. CONCLUSION

From the results gained, the growth or enlargement of the water spinach (plant) was successfully evaluated. By indoor vertical farming system, it can water the plants automatically using analog timer plug at set time. This can fit the user needs in order to start plants the vegetables, fruits or foods in indoor or in houses. When everything has been set up and the seeds have been sown, just

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need to put it into the indoor vertical farming system and wait until the plants can be harvested and served on a plate. Hence, the development of the system was studied and modified based on the objectives of this project. The use of indoor vertical farming system can be continued by replanting other vegetables in it after the previous plants have been harvested. Since this system was more convenient to use and effective, the system is critical to the application for indoor farming. Besides that, this project development can be used as a good reference for future studies that can be implemented in the agriculture system.

Coronavirus or Covid-19, a pandemic that has kept many residents indoors, is the current issue affecting the neighbourhood. Furthermore, there is a lack of foods or fresh veggies in the market as a result of this. This project and study given an idea for a product that will help the community generate fresh veggies from their own homes, even if they live in a flat house location and lack the room to grow their own food. With this product, not only is it easier for people in the community to obtain fresh vegetables, but it also gives them incentive to start their own gardens, no matter how tiny. An indoor vertical farming system has been around for a long time, and this product is a type of system that uses water and lighting as the primary medium for growing vegetables. The vast majority of this products on the market are huge in size and employed by large-scale vegetable producers only. As a result, small-scale and simple items that can be installed in small locations, like as automatic watering systems and long-lasting water containers, are excellent for production in homes with limited space can get from this indoor vertical farming. The design was established and the final design was selected as the best design aesthetic to be developed based on the fundamental requirements and criteria.

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