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Rainwater Harvesting As a Technological Innovation to Supplying Crop Nutrition through Fertigation

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Abstract — Water management in agricultural production is accomplished primarily through a combination of the irrigation and fertilizer. Irrigation couple with fertilizer is the process of supplying fertilizer or nutrients to crops in the irrigation water as a technological innovation in agricultural sector. The interdependence of irrigation and fertilizer has been recognized in most part of the word where irrigated agriculture is practiced. Fertigation become closely linked component in an overall system for water management in agricultural production. The concept of rainwater harvesting in wet season and supplying it to crops through fertigation was introduced as a part a wider theoretical as a technological innovation. Rainwater from the roof of a greenhouse in periodically harvested and stored in torrents for later use. The purpose of this study was to evaluate total volume of rainwater harvesting where as the use of consumptive use to plant red tomato cherry as a source of fertigation in dry and wet season. This research was carried out from January until May 2016 which is located in the green house of Padjadjaran University campus, Jatinangor Sumedang , West Java Indonesia. The results show that rainwater harvesting from greenhouse roofs top and applied it as fertigation in the wet season good enough of consumptive use whole year (wet and dry season) for planted red tomato cherry.
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Keywords — Fertigation; Innovation Technology; Rainwater Harvesting; Self Watering System

I. INTRODUCTION

Fertigation engineering is the application of supplying irrigation and fertilizer to crops and engineering principles to solution of water management problems. Modern concept of irrigation such as fertigation has been made possible only by application of modern power sources to rainwater harvesting and by the storage to the big torrents or a storage tank of water reservoirs. Lee, et.al [1] noted that with increasing demands for water and with limited supplies available (due to climate global change) more effective use of water as irrigation. The irrigation requirement is the quantity of water, to be supplied to crops. Irrigation requirements are dependent not only on evapotranspiration but also on water application efficiency, water supplied and by rainfall especially effective rainfall.

Water requirement vary with different crops; although growing crops are continuously using water the rate of evapotranspiration depends on kind of crops, degree of maturity, and environment condition, such as humidity, wind and temperature. According with Ahmad, et al[2] that the uniformity of water distribution (UDC) is one of the main parameters for evaluation of fertigation; where UDC is defined as a measure of water supply which relates to the fourth part of the total area which receives the least water, with the average water depth applied. To make maximum use of available water, the fertigation should have a knowledge of the water requirements of crops at all times during the growing season; it may possible to select the crop to fit the water supply.

A. Rainwater Harvesting

Rainwater harvesting is the collection and storage for reuse on-site, these stored water are use for various purpose such as gardening, fertigation and other in agriculture sectors. The surface that receives rainfall can directly for catchment of rainwater harvesting system, or from roof top or sloping roof top.

The methods of rainwater harvesting is to collected rainfall for examples in this research from building of the green house root top is diverted to storage of big torrents . The storage tank has to be calculated depend on to the water requirements, amount of rainfall and catchment availability. Storage water from the torrents can be applied for fertigation in the green house automatically and efficiency.

The collection of rainwater from the green house rooftop easily to capture and storage it to a rainwater storage such as tanks or torrents and we have resource of irrigation water in the dry season. By capturing water directly we can also significantly reduce our reliance on water storage dams, and if suppose water tanks not enough to collect water harvesting we can build new ones tanks or torrents. The advantages of rainwater harvesting these are:

1. Rainwater harvesting can capturing directly
2. Size of tanks or torrent can be chosen by quantitavely assessing the performance of various storage capacity; the other world that the size of particular storage capacity can be judged with among of rainfall how much water is required to be supplied and demand for fertigation in season or a year.
3. If crops plant in the green house; supply and demand of water application can also high efficiency and also reduce the cost

Fig 1. Rainwater Harvesting System for Irrigation

Rainwater harvesting from root top have several disadvantages these are:

1. Rainwater harvesting which for the first flow of water to the rainwater storage tank to be diverted from the tank. By doing this, any dirty on the roofs top of building that has built up prior to the rain can be excluded from the tank.
2. Estimating the amount of capture rainfall as supply water that is able to be collected depend of amount of rainfall and the size of tanks or torrents
3. Estimation of the area of capture or roof top area must also be known when estimating the amount water rain harvesting; the larger the roof top area, the more rainfall that to be able to be collected.

B. Supplying Crops Nutrition through Autopot Fertigation

Fertilizer can be applied together with using any irrigation method[3]–[7]; for example by surface irrigation ; sub surface irrigation; sprinkler irrigation and drip irrigation methods respectively. The most common system used for fertigation and requires the most knowledge for effective use[8]. Fertigation is the process of supplying fertilizing plant through irrigation; which are distribute both water and fertilizers. This article or research will discuss fertigation using hydroponic system that can be used crops such as red oval cherry tomato cultivated in autopot at the green house.

The high efficiency of fertigation are due to (1) fertigation soaking into the closed auto pot where crops grown; (2) low evaporation; (3) application of fertigation will stop by automation valve in autopots; so it mean application of fertigation only where it is needed. The other advantage of direct fertigation to the auto pot in the green house is to reduces water contact with soil water and ground water; thus making condition less favourable for many diseases and pests it will impact crops clean and fresh.

According to Miles; et.al[8]; in fertigation system any nutrients in a soluble from are available for plant uptake right application, allowing the farmer greater control over nutrient availability to the crops. Some advantages of fertigation to crops are:

1. More efficient and effective by combining the irrigation and fertilizing need
2. Plants absorption rate increase up to 90%
3. Decrease the risk of disease and pests so crops become healthy
4. Decrease of chemical impact of the chemical exposure, because nutrients used liquid fertilizer
5. More efficient and effective because less laborious

Fig 2. Autopot Fertigation System for Red Oval Cherry Tomato

Disadvantage of fertigation is nutrient based on liquid fertilizer; in the develop countries plant nutrients through fertigation to supplementing controlled release fertilizer through to complete liquid feed or hydroponic programs. Supplying crop nutrition through fertigation and grow the plants in autopot system is a technological innovation because an efficient and environmentally friendly technology that revolves around the smartvalve, which feeds plants on demand. Some benefit with autopots combining with fertigation are[9]:

1. Resource water efficiency, there is no water wastage or nutrient runoff as plant feed on demand
2. Environmentally friendly; without nutrient runoff is no pollution to surrounding water systems
3. Automated and simple; because this system is fully automated, farming such as non-production or marginal land, or even rooftops

4. Automated and simple; because this system is fully automated, farming on a commercial scale become easier and less laborious
5. Consistent; because crop yield quantity and quality are consistent

Fertigation technology autopot operated via smart-valve used for opening and closing the irrigation water automatically based on the condition of the water in the pot[9][10]. The water level in the pot is used as a mechanical sensor smart-valve to close and open automatically without the assistance of others Figure 3. This is what gives an advantage for the self-watering system for both urban developed as part of urban agriculture. Advantages of self-watering system in agriculture, especially agriculture with high-value commodity crops among others: 1) efficient use of water, 2) the provision of water as needed, 3) does not require electrical power / low energy, 4) cost of maintenance, and 5) scheduling independent.

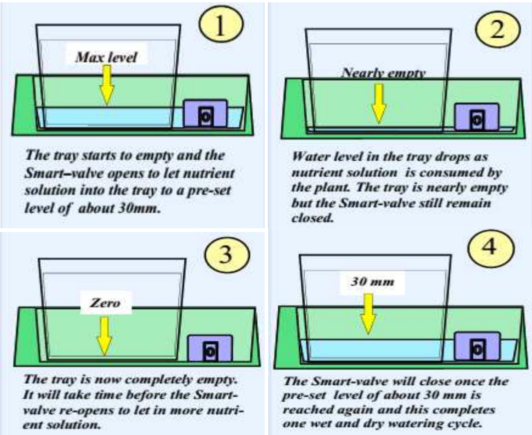
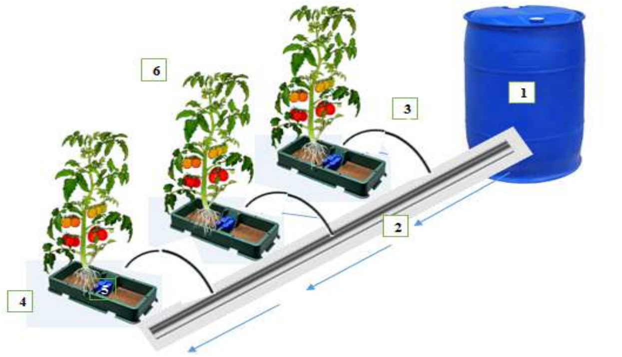


Fig 3. Water circulation of Autopot System

II. Material And Methods

The research was conducted in January to May 2016, at the North Pedca Greenhouse FTIP Unpad, District Jatinangor, Sumedang, West Java province of Indonesia. This study was conducted to examine the response of the use of various organic growing medium composition on the growth and productivity of the cherry tomato plants are cultivated using the Autopot fertigation system.

The tools used in the form of autopot fertigation network as shows in Figure 4. Plant nutrients stored in a tank then poured into a pot/tray through the main pipe and a lateral pipe which is connected to smart-valve installed in the pot. The measuring tool i.e. digital thermo-hygrometer, lux meter, pan evaporation and water/nutrient quality measuring instrument. While the materials used growing medium (husks charcoal, compost, humus, and cocopeat), tomato seeds, water, and nutrients. The irrigation water used in the form of rainwater harvested from the greenhouse roof and collected in the water tank.



Note :
1. Nutrient Tank; 2. Main Pipe; 3. Lateral Pipe; 4. Autopot; *5. Smart Valve* ;6. Cherry Tomatoe

Fig 4. Autopot Working System

In this study, Autopot technology used in the cultivation of cherry tomatoes using three composition of growing medium, that are husks husks charcoal + compost (M1), husks charcoal + humus (M2), and husks charcoal + cocopeat (M3) with a composition of 50%: 50%. The supplement observations were made of the research are:

(1) the physical properties of growing media include BD (Bulk Density), moisture content, specific gravity, porosity, and permeability;
(2) Greenhouse microclimate parameters, i.e maximum and minimum humidity, maximum and minimum temperatures and light intensities that measured at 07.00 am, 12.00 pm, and 17:00 pm;

While the main observations were made of the research are

(1) Response to the use of various compositions of growing media on growth of cherry tomatoes.
(2) Calculation of crop water consumptive use with equation[9] as follow:

$$Water\ Consumptive\ Use = \frac{Used\ of\ Water\ Daily}{Total\ Crop} \quad (1)$$

(3) Response to the use of various compositions of growing media on yield of cherry tomatoes.

III. Results And Discussion

A. Physical Characteristics of Growing Media

The parameters tested in determining the physical characteristics of the planting medium that is associated with BD (Bulk Density), moisture content, specific gravity, porosity, and permeability. Table 1 shows the water content value of the water content of the media M1 (Husks Charcoal + Compost) of 54.9% by volume, nearly equal to the water content of the planting medium M2 (Husks Charcoal + Humus) amounted to 59.8%. While the water content of the planting medium M3 (Husks Charcoal + Cocopeat) amounted to 73.1%. The high level of water content in the growing media M3 showed that the addition of cocopeat will increase the amount of water that can be held by the growing medium.

TABLE I
GROWING MEDIUM PHYSICAL CHARACTERISTIC

Physical Characteristic	Media		
	M1	M2	M3
Water Content (% vol)	54,9	59,8	73,1
Bulk Density (g/cc)	0,53	0,46	0,21
Particle Density (g/cc)	1,71	1,62	1,48
Total Pore (% vol)	69,3	71,6	85,8
Moisture Content (% vol) Field Capacity pF 2.54 Permanent Wilting Point pF.4.2	 38.3 17	 34.6 15.9	 29.5 13.8

The value of bulk density on the medium M1 amounted to 0.53 g / cc then M2 0.46 g / cc and M3 of 0.21 g / cc. The weight of the contents of the M3 have the value of which is low, it means that a number of solids fewer causing high pore planting medium. Therefore, the water content in M3 was higher than other growing media. This leads to optimal plant growth is not due to a root decay. Inversely proportional to the condition of the M1 and M2 which have a more optimal growth.

The value of specific gravity on the M1 amounted to 1.71 g / cc, M2 1.62 g / cc, and M3 amounted to 1.48 g / cc. M1 has a specific gravity at a higher value so that a number of solids to the absorption of nutrients in decomposing nutrients better than the M2 and M3. Specific gravity is also strongly related to the bulk density and total pore space. Table I show the value of total pore space planting medium M1 amounted to 69.3%, 71.6% M2 and M3 amounted to 85.8%, from these data we can conclude the planting medium pore space M3 has great value, it means the ratio of the amount of empty space occupied by more water than growing media M1 and M2. This causes the plant growth in the M3 medium is less than optimal, caused by too much water content contained in the pore spaces of the growing media M3, and resulted in the decay of plant roots.

Value of the moisture content at different levels of pressure on M1 is greater than the M2 and M3. It shows the state of water availability from field capacity to permanent wilting point in M1 more than the M2 and M3. That affect productivity and water use fertigation more on the media M1, but in the state of saturation water content of M1 is lower compared with the M2 and M3, it may be useful for growing media M1 to avoid the decay of plant roots. Based on the data, available water value of M1 at 21.3%, and M2 by 18.7% and M3 by 15.7%. From these data, we can conclude M1 has an available water content of more than M2 and M3 so that the water content available on the M1 can support towards optimum plant growth.

B. Greenhouse microclimate conditions

Observations microclimate conditions in the greenhouse were conducted to determine the environmental suitability conditions on plant growth[11][12]. Based on the graph in Figure 4. The intensity of light with an average value for 10 hours at 07.00 am at 8006.90 lux, at noon at 33675.37 12.00 lux, and at 17.00 pm today at 2762.22 lux. According to Olley[11] optimal tomato growth at an intensity of 482-540 lux * 1000. Olley[11] stated climate requirements desired by the cherry tomato plants require sunlight is a minimum of 8 hours per day so the plants can grow optimally.

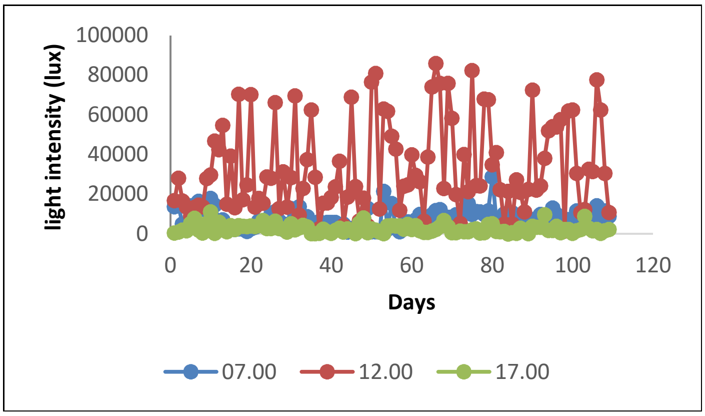


Fig 5. Light Intensity During Cherry Tomatoes Growth

The observation of the environmental temperature can be seen in Figure 5. The data shows the temperature measurement values fluctuating temperatures. This can be overcome by climate modification is the measurement of humidity and temperature stability through fogging technology so that it can be adjusted in order to remain in optimal condition for the growth of plants. The minimum temperature maintained its stability in order to not less than 18ºC, while the maximum temperature is maintained a stability of not more than 30ºC. According to Mattsons and Peter[12] with the hydroponic system can set the environmental conditions such as temperature, relative humidity, and light intensity, even rainfall factor can be eliminated altogether so that the pest attack can be minimized.

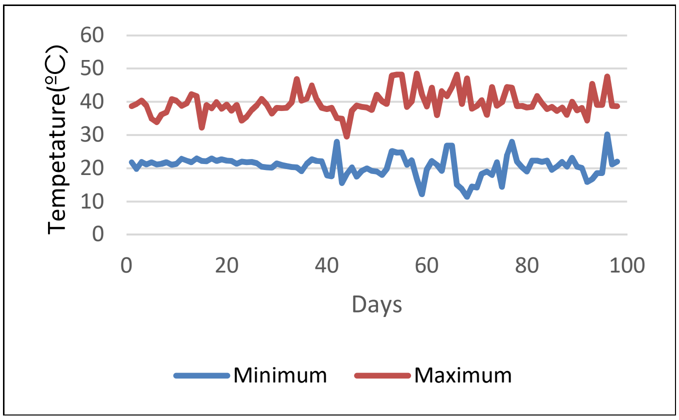


Fig 6. Temperature Condition During Plantation

According Mattsons and Peter [12] for the growth temperature ranges from 25-30^{o}C cherry tomato plant with a humidity level of 50-70%. From the measurement data in the field as at present in Figure 5 and Figure 6 note that the maximum value of temperature and humidity that occur in the greenhouse exceeds the range needed, especially during the daytime. In this condition, fogging is done to lower the ambient temperature and humidity increase.

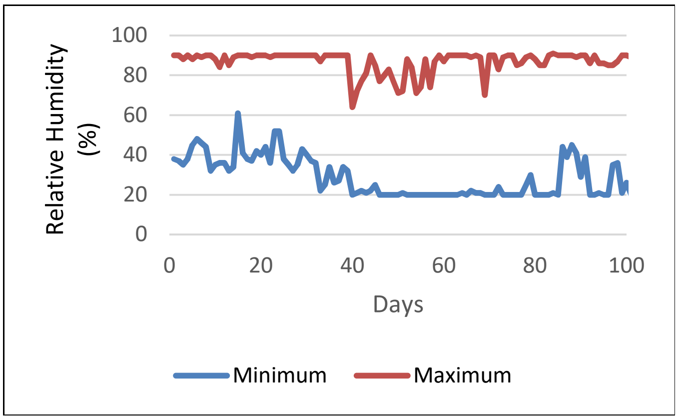


Fig 7. Humidity Condition During Plantation

In addition to the intensity of the sun, the temperature and humidity, in this study also conducted using the evaporation pan evaporation measurements. Figure 7 below shows a comparison of the value of evaporation in the greenhouse and outside the greenhouse is taken from weather stations of Padjadjaran University.

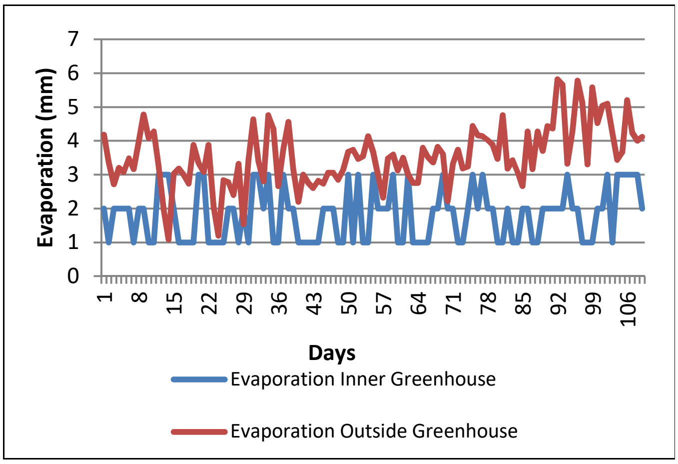


Fig 8. Differences in evaporation values inside and outside the greenhouse

Based on Figure 7, the evaporation that occurs outside the greenhouse is higher than the evaporation in the greenhouse. The average evaporation in the greenhouse was 1.76 mm / day while the average evaporation outside the greenhouse was 3.6 mm / day. If the note even though the average temperature in the greenhouse (30.5 ° C) higher than the temperature outside the greenhouse (21.2 ° C). This indicates that the value of evaporation is not only determined by the temperature but is also influenced by other factors, namely the wind. Jatinangor has a wind speed of less than 4 m / sec, while in the greenhouse wind factor not taken into account because it was blocked by building the greenhouse.

C. *Cherry Tomato Plant Growth Response*

Parameters used in the plant morphological observation of cherry tomato is the measurements of the plant height and width of the leaves from the early transplanting until near harvest time. Measurement height and width leaves the planting is done once a week. Field measurement results can be seen in Figure 8 below.

Based on observations of plant height as shown in Figure 8 is known that the use of different growth media resulted in a very different response. In the early weeks after planting, high growth charts cherry tomato plants did not show a significant difference between the cherry tomatoes grown in medium M1, M2 and M3. The second week after planting, and so is known that the cherry tomato plants grown with the media M1 provide the best results. But the different conditions are shown in the cherry tomato plants grown in M3 media. Cherry tomatoes grown in M3 media does not give good results, even at the end of week 9 after planting mostly planted withered and dried up.

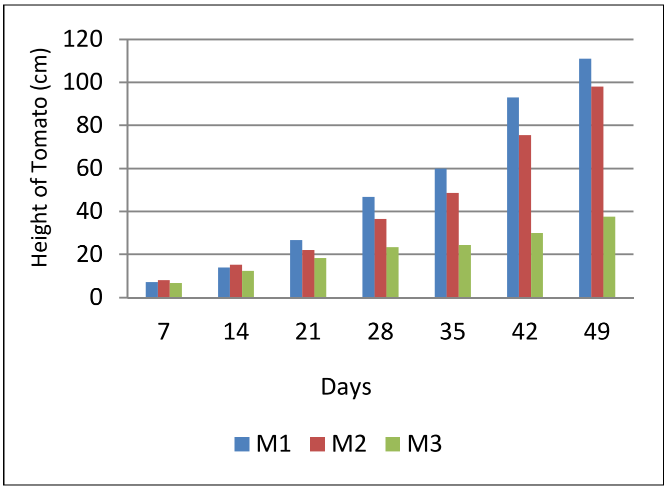


Fig 8. Height of Cherry Tomatoes During Plantation

A similar response occurs in a wide observation of the leaves, which are planted with cherry tomatoes M1 media showed the best results, while the M3 media does not give a good response (Figure 9). In the generative phase subsequently happens to condition the planting medium M3 are plants that die in the eighth week it begins with a condition of the plant begins to wilt in the sixth week it is directly proportional to the analysis of physical characteristics to the growing media M3 occurrence of root rot caused by a number of the moisture content is too high.

D. *Water Consumptive Use of Cherry Tomatoes*

According to Nurpilihan et.al, [13] observations on the water consumptive use cherry tomatoes are cultivated done by calculating the total amount of water consumed by the plant for evaporation, and metabolic activity of plant transpiration. The measurement procedure is done by reducing the volume of water in the nutrients tank. The value of water consumptive use per day is obtained from the reduction of nutrient water volume the previous day with the nutrition water volume on the day of measurement. Irrigation water comes from rainwater collected in water tanks and then piped into the tank of nutrition. The observation of water consumptive use can be seen in Figure 10. Figure 10 shows that the total water consumptive use cherry tomatoes at growing media M1 and M2 were not significantly different, with amount of water usage for M1 equal to 882.32 liter and 784.28 for M2. While the M3 media showed a much different value, total water used in the third medias are 294.1 liter . Consumption of nutrients and minerals by the roots of plants is done through planting[5]. Thus the root condition will affect nutrient uptake and use of water; if the roots are healthy then the uptake of water and nutrients will not be disturbed so that the growth of plants is also not disturbed[14]. Cherry tomato plant roots are planted using growing media husk charcoal + cocopeat (M3) is not well developed, even from week six to week eight most crops suffered root rot, so the plants wither and even death.

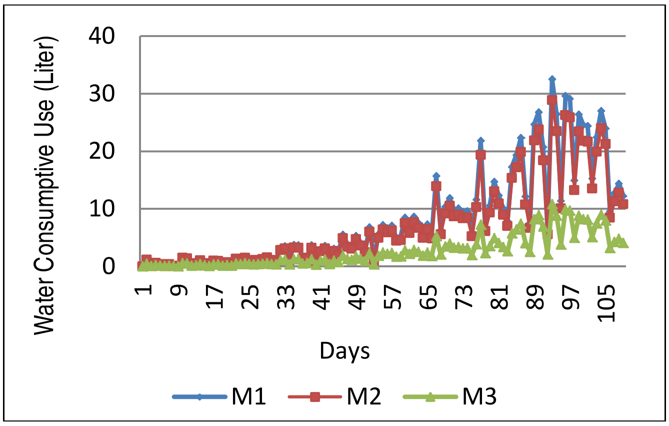


Figure 10. Water Consumptive Use For Differences Growing Media

E. Yield of Red Oval Cherry Tomatoes

Observations productivity cherry tomatoes cultivated with autopot technology uses three different kinds of planting medium is done at harvest time. Parameters measured were heavy yields and the number of fruit per plant per one harvest. The average production of cherry tomatoes on the growing media tested can be seen in Table II below.

TABLE II
CHERRY TOMATOES YIELD

Growing Media	**M_1**	**M_2**	**M_3**
Numbers of Fruit per crop	186	113	24
Total harvest weight per crop (kg)	4.72	2.48	0.45

Based on the value of the cherry tomato plant productivity is the most optimal planting medium M1, and M2, M3, and most recently, the yield value of 4.72 kg in M1, M2 2.48 kg and 0.45 kg in the M3, from these data we can conclude M1 yield higher than other growing medium, it is directly proportional to a number of nutrients and water are absorbed by the growing media M1. According to literature the production of cherry tomatoes were 2 to 3 kg per plant. Cultivation of cherry tomatoes with autopot using growing media of husk charcoal and compost gives a higher production.

IV. CONCLUSIONS

Based on the physical characteristics of the planting medium, the composition of husk charcoal + compost media (M1) have the most optimal results for cherry tomato plant growth. Total water used at growing media M1 and M2 were not significantly different, whereas on M3 media is much smaller than others, this is because the root of cherry tomato on M3 media cannot grow well. Cherry tomatoes grown with husk charcoal + compost media (M1) provide higher yields than other media, with the average of yield is 4.7 kg per plant. Thus the application of technology autopot the hydroponic cultivation of cherry tomato plant using husk charcoal + compost growing media with a composition of 50%: 50% proved to increase productivity with the cherry tomatoes without relying on the use of electrical energy to circulate water and nutrients.

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