

Water Harvesting System as an Alternative Appropriate Technology to Supply Irrigation on Red Oval Cherry Tomato Production

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Abstract— Water harvesting is a system which starts from harvesting rainfall in the wet season and collecting it in the big torrents, as irrigation resources and applied to the crops in the dry season for increased crop production. Horticulture crops such as red oval cherry tomato is predominantly an Indonesian crops for domestic and to support agro-industry sectors, which requires effective and efficient water management practice during the growth periods. Modification of irrigation system needs to optimize water and improve the red oval cherry tomato production. The study aims to find out water used by red oval cherry tomato with related irrigation resources from a supply of water harvesting as an appropriate technology in the dry season. The research was carried out at the greenhouse located in Universitas Padjadjaran; West Java, Indonesia from January to Mei 2017. The research method is descriptive analysis with cultivated of red oval cherry tomato and planted it on the autopot with growth media uses mixed of husk charcoal and zeolite with ratio 9:1 with 15 cm height. This study discovers that the rainwater harvesting as a source of irrigation on self-watering fertigation system using autopot can be beneficial for red oval cherry tomato yield.

Keywords— Water Harvesting; Irrigation Resources; Crop Production; Autopot Fertigation System.

I. INTRODUCTION

Indonesia has a geographical position as the island nation located around the equator that gets the distribution of rainfall very markedly[1]. Variations in annual rainfall in the archipelago region in Indonesia are very high; there are areas with annual rainfall reaching 4000 mm while in the other areas less than 800 mm/year. This rain is concentrated during the approximately five months from November until March [2], so in these months many areas flooded. While in the seven months when rainfall is minimal, resulting limited water availability causes drought in the dry season and many regions experience water shortages. Supposedly, the high rainfall could be used by doing rainwater harvesting that is capturing water in the rainy season and utilized at the time of the drought.

Water is one critical factor in the agriculture sector and becomes the first barrier factor in agriculture production. The limitation of water resources availability may obviously cause irrigation requirement. To actualize fairly and equality, the Indonesian Government, settled the regulation on irrigation management which should be fundamentally adhered. In the dry season, water availability for irrigation is

a problem that has to be overcome, to keep water availability without depending on the season, the expertises should be able to find the appropriate technology that can be used by the farmers especially in the rural areas. The limited supply of irrigation water and the high demand to meet the water needs of the plants require water-saving efforts. Rainfall harvesting is one of the alternative solutions because water could be collected in the wet season, store it in the tank or torrents and can be applied for irrigation.

Water use different from numerous and period stage of plants[3], [4]. Increasing demands of water with limited supplies availability; in this case need more efficient of water use; or water conservation in the soil; increasing water used of efficiency can become an alternative to prevent water deficiency.

A. Rainfall harvesting.

Rainfall harvesting is the accumulation and storage of rainwater for reuse on-site, rather than allowing it of runoff. Rainwater can be collected from many various of places; such as rooftop of building; the water collected is redirected to a deep pit or other reservoir of water. Its can be uses for

agro complex need as a irrigation, livestock, industry and domestic use.

Rainfall harvesting means capturing rainfall where it falls or capturing the runoff from the rooftop in urban or rural areas [2], [5] as illustrated in Figure 1. Rainfall harvesting can be undertaken through a variety of ways these are:

1. Capturing rainfall from rooftop
2. Capturing rainfall from local catchments
3. Capturing seasonal floodwaters from local streams, and
4. Conserving water through watershed management.

In general, water harvesting is the activity of direct collection of rainwater. The rainfall collected can be stored for immediate use or can be recharged into the groundwater. Rainfall collection and stored it in tanks is useful for resources of irrigation; livestock water supply, or landscape watering. In other words, collected rainfall has proven the value of harvesting rainwater for outdoor use. The collection of rainfall harvesting falling over an area cannot be efficiently harvested because of evapotranspiration and spillage. In Indonesia, water harvesting usually are collected in wet season; while in dry season water harvesting can be considered as irrigation source.



Fig 1. Rooftop Rainwater Harvesting System for Agriculture

Rainwater harvesting technology is appropriate for arid and semi-arid countries affected by global climate change. Water harvesting widely practiced in the heavy rainfall and more benefit such as reducing water supply cost. In this research water harvesting is collected from rooftop of the greenhouse and conveyed to the storage system through gutter and conveyor pipe as shown in Figure 1. Roof constructed from polycarbonate material. The storage system consist from four big torrent (5300 liter for each torrent). Rainwater collected are used as irrigation combined with fertilizer (fertigation) for the cultivation of cherry tomatoes in the greenhouse.

B. Fertigation

Water and nutrients are the essential requirements for plant growth, and performance and leaf water supply constitutes the overwhelming limitation on plant productivity[6]. Fertigation is a process that combines fertilization and irrigation; this methods commonly use in horticulture production such as cherry tomato. Fertigation method adds the correct amount of fertilizer according to the plant's nutrient deficiencies. Fertigation methods will reduce soil erosion; minimized the risk of the roots; controlling soil-bone disease; reduces water consumption; reduces amount

of fertilizer used; increasing the nutrient absorbed by plant and controls the precises time and rate of fertilizer being released. The delivery of dissolved mineral fertilizers to the roots of crops in the field using irrigation water is known as fertigation[4]. The use of fertigation is gaining popularity because of it is efficiencies in nutrient management time and labor and potentially a greater control over the crop. Fertigation engineering is the application of supplying irrigation and fertilizer to plants and engineering principles to the solution of water management problem [3], [7]–[9]. The modern concept of irrigation such as fertigation has been made possible only by the application of modern power resources to rainfall harvesting and by storage to the big torrent or storage tank of water reservoirs [3], [10], [11].

The advantages of supplying mineral nutrients to crop roots fertigation include[9], [12]:

1. Reduced delivery costs because no need to broadcast fertilizers, leading to less soil compaction in the inter-row areas, less fuel usage and lower labor requirements.
2. Greater control over where and when nutrients are delivered, leading to higher use efficiency
3. More control over crop behavior through targeted application of specific nutrients during particular stages of crop development

4. The potential for reduced fertilizer losses (due to immobilization within or leaching below the root zone) by supplying small amount often.

Besides advantages of fertigation where have several disadvantaged these include[12]:

- a. Higher capital costs with the equipment needed to dissolve and inject the fertilizer into the irrigation water
- b. Higher operating costs with using technical grade fertilizer as opposed to agricultural grade fertilizers
- c. The chemical reaction between some types of fertilizer when mixed potentially causing significant equipment blockages.

There are two main types of fertigation approaches; these are:

1. The proportional approach is used in soil-less medium where a precise quantity of fertilizer stock solution is injected into each unit of water flowing through the irrigation system.
2. The quantitative approach is used in open fields where the horticulturalists first decides how much fertilizer should be applied per unit area.

This research was use the type of fertigation approach number one above.

Grade fertilizer is not suitable to use fertilizer system because of the amount of impurities present which may be insoluble and lead to dripper blockages. For this reason, technical grade fertilizers are required in fertigation systems because they have fewer impurities and proportionally higher levels of the desired mineral nutrients[7], [13]. Using fertigation is to manage crop performance need to be based on a good knowledge of when and to what extent each mineral nutrient is taken up by the crop's root and how it affects crop growth development and yield. Another gap in this technology is the ability to measure crop nutrient status in real time and to interpret that information correctly and use it to manage to fertigation system[9].

The autopot is one of latest technology an efficient and environment-friendly technology that revolves around the SmartValve, which feeds plants on demand. Fertigation combined with autopot fed with nutrient-rich water; the crop is protected from soil-borne diseases and are kept healthy without the use of harmful chemicals. Autopot combined with fertigation is one of new technology today to increase agriculture productivity. Through the use of this technology, we have developed a sustainable method of farming that does not depend on soil condition. And can be applied almost anywhere, we have implemented our agricultural system to provide a livelihood to rural folk who previously had no means to support themselves. There is some benefit of autopot [14]. First, water resource and fertigation efficiency; there is no water wastage, or nutrient came out from the autopot as plant feed on demand. Second, environmentally friendly; without nutrient and water from fertigation came out from the autopot; there is pollution to surrounding water systems. Third, flexibility, the system allows for agriculture to thieves in areas that would usually be seen as nonconductivity to farming such as nonproductive or marginal land or even rooftops. Fourth, automatic and simple, this system is fully automated, planting on a commercial scale becomes more straightforward and less

laborious. And fifth, consistent, crop yield quantity and quality are consistent.



Fig. 2 Smart-Valve and this position in autopot [14]

Autopot system is an efficient and environmentally-friendly technology that revolves around the smartvalve, which feeds plants on demand[5]. Smart tray of autopot very suitable for planting fruits, such as cherry tomato, melon and vegetables. The Smart-Valve is the heart of the autopot system (Figure 2). When connected to water supply or nutrition solution, the valve opens to allow water to enter the bottom of the growing media to a pre determined and pre set water depth (usually 35 mm). The valve then closes and will permit no further solution to enter the container until all the solution absorption in the growing media. After the solution has been absorbed, the valve re-open and the another solution of nutrition enters the growing chamber. This research uses smart tray double autopot; it means double planting point for cherry tomato in one smart tray.

II. MATERIAL AND METHODS

This research was held from January until May 2016, was carried out at the greenhouse located in the campus of Universitas Padjadjaran, Indonesia from January to Mei 2017. The research method is descriptive analysis with cultivated of red oval cherry tomato and planted it on the autopot with growth media uses mixed of charcoal husk and zeolite with ratio 9:1 and 15 cm height.

Plant nutrients stored in a small tank than applied it into the autopot through the main pipe and lateral pipe which is connected to a smart valve. Irrigation resources from rainfall harvesting which capture from the rooftop of the greenhouse and collected in the big torrents at outdoor the greenhouse.

The research observed follow:

- a. *Calculated potential of rainwater that could be harvested*

Rainwater that can be harvested is calculated using the following equation [15]:

$$V = A \times R \times c \dots \dots \dots (1)$$

Whereas, V is the volume of potential rainwater that could be harvested (m³); A, rooftop area (m²); R, the annual rainfall with 80% probability exceeded (mm); and c, runoff coefficient.

b. Water consumptive use

Consumptive water is the total amount of water used by plants (ETc). Consumptive water measurements are done every day at 07.00 by measuring the reduction of water in nutrient drums. Nutrition drums connect directly to autopot via pipelines[4].

c. Yield of red oval cherry tomato

Harvesting of tomatoes is done on plants that have been aged 60-100 days after planting. Harvesting is done by picking fruit that is colored 'dark red'. The harvest weight is obtained from the total weight of the harvest in each crop.

d. Water used efficiency

The efficiency of water use (WUE) is the result of harvest produced with the required water. According to Nurpilihan et al.[3] water use efficiency (WUE) can be calculated using the equation below:

$$WUE = \frac{\text{Total Yield}}{\text{Total Water Use}} \dots \dots \dots (2)$$

Where total yield is expressed in kg, total water use expressed in m³ and water use efficiency (WUE) is expressed in kg m⁻³.

III. RESULTS AND DISCUSSION

A. Potential of rainwater that could be harvested

Research on rainwater harvesting as a source of irrigation water is done by harvesting rainfall from the roof of a greenhouse as illustrated in Figure 1. Rainwater falling on the roof is captured and flowed to the gutter and then collected in two container tanks and distribution tanks. The water then flowed into the nutrient tank inside the greenhouse and then rushed into the autopot fertigation network as shown in Figure 3.



Fig. 3 Autopot fertigation network in the greenhouse

The catchment area of the greenhouse rooftop is 150 m². Greenhouse rooftop is made of polycarbonate material with

runoff coefficient value of 0.90; it means that 90% of the rain falling on the roof will become a runoff.

An understanding of the pattern and distribution of rainfall in the location of research became the basis the potential of the rainfall that can be harvested from the greenhouse roof. Analysis of the rainfall region calculated by the method of Thiessen. Rainfall in the research location 97% is determined by rainfall data from Pedca station and 3 percent was determined by rainfall data from Jatiroke Station.

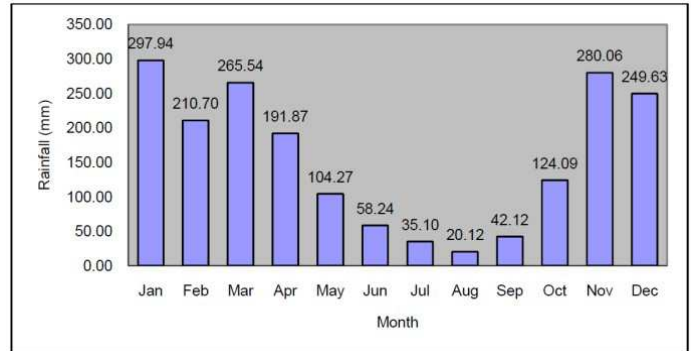


Fig. 4 Distribution of Monthly Rainfall in Jatianangor

Based on the analysis of rainfall, Jatianangor research center has annual rainfall of 1879.69 mm. Based on the amount of annual rainfall, then the location of the study are included in the category of dry land with wet climates where rainfall more than 1,500 mm / year[16]. Meanwhile, based Oldeman climate classification known that Jatianangor region has five of wet months (NDJFM) where monthly rainfall > 200mm; four dry month (JJAS) where monthly rainfall <100 mm and three humid months (monthly rainfall between 100 -200 mm per month), as can be seen in Figure 4.

Dwiratna et.al (2018) state that annual rainfall with an 80% probability is exceeded at the research site is 1500 mm. Thus, the amount of rainwater that can be harvested from the rooftop of the greenhouse is 202.5 m³ per year. In the study, the volume of storage used was 21.2 m³.

B. Water consumptive use

The value of plant evapotranspiration (ETc) is derived from consumptive water use by the plant as calculated from the water depletion on the nutrient drum each day. The amount of water used by red oval cherry tomato plants in each growing phase can be seen in Table 1. In the table, it can be seen that the total water used for red oval cherry tomato plants in one period grows at 71 liters/plant.

Water use continues to increase in each phase, and there is a decrease in the late season phase. The most water use is in the mid-season phase of 60 liters/plant and the least use of water in the initial phase of 1 liters/plant. The total water requirement of red oval cherry tomato plants during one planting period using autopot is 71 liters/crop or 382 mm. According to FAO data, the total requirement of tomato plant water is 600 mm[17]. Figure 5 shows the comparison of ETc values of measurements with ETc resulting from FAO.

TABLE I
WATER CONSUMPTIVE USE OF RED OVAL CHERRY TOMATO

Growth State	Total Water Use (liter)	Average Water Consumptive Use Per Crop	
		Liter	mm
Initial (20 days)	66	1	3
Development (20 days)	362	7	38
Mid Season (95 days)	3100	60	325
Late Season (10 days)	149	3	16
Total	3677	71	382

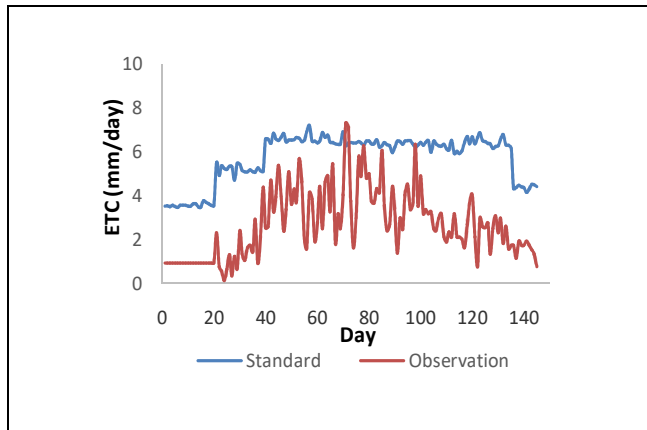


Fig. 5 Value comparison Consumption use of cherry tomato water using autopot And FAO standard

From Figure 5 it can be seen that the value of plant evapotranspiration (ETc) increases with the growth and development of the plant and then decreases at the late season of planting. ETc value in the initial phase is 0.16 mm / day at the age of plants of 1-20 days. ETc value in the development phase at 21-39 days after planting of 1.9 mm / day. The amount of ETc in the mid-season phase of the plant age 40-135 days after planting, ie, 3.42 mm/day and in the late season phase of ETc value of 1.56 mm/day at the plant age of 136-145 days after planting. When compared to FAO data the use of water to meet the water needs of cherry tomato plants using autopot technology uses more efficient.

C. Red oval cherry tomato yields

The way to determine the harvest index is to distinguish the physical-chemical changes that occur during the fruit ripening process from the maturity level of young to old, green mature, breaker, turning, pink, light red and red respectively[18]–[20]. Flowering starts to occur when the plant is three weeks after planting (WAP), and flowers begin to bloom (anthesis) when the plant enters the age of 4 WAP. The fruit has already set to form when the plant is 5 WAP. The first harvest started when the plant was 8 WAP.

The time of cultivation to early fruit harvesting depends on cultivars and growth conditions, and can range from 70 days to 125 days; most tomatoes mature 35-60 days after anthesis (9-12 MST). Harvesting is done periodically that is 2-3 days interval once. The measurement of cherry tomato yield is done by weighing fruit per plant.

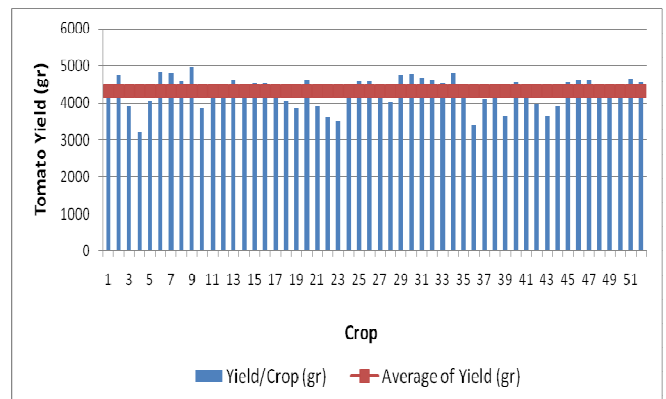


Fig. 6 Total Yield of Cherry Tomato per Plant

The results of observation of cherry tomato plant production using autopot can be seen in Figure 6. The result of observation shows that the average yield of 20 harvests per plant varies. The average weight of crop yields of 4.321 kg per crop. The highest yield was 4.954 kg per crop of harvest, and the lowest was 3.201 kg per crop.

D. Water used efficiency

The water use of efficiency (WUE) is calculated using Equation 2. Water use efficiency is the ratio of total yield per unit of water used. The results show that the efficiency of water use in cherry tomato cultivation using autopot is 61.73 kg m^{-3} . Low water use and high production can increase efficiency. This is supported by Nurpilihan et.al [4]statement, that the higher the crop yield, the higher the efficiency value of water use. The higher the use of water, the lower the efficiency. To increase the efficiency can be achieved by increasing the amount of dry matter or yield for each unit of water volume provided.

IV. CONCLUSIONS

The amount of rainfall potential that can be harvested from the greenhouse roof is 202.5 m³ per year; this value is sufficient to be used as an irrigation water source especially in the dry season. The average yield of cherry tomato plants using aut opot combined with fertigation is 4.321 kg per crop with the highest yield of 4.954 kg. The value of water use efficiency of cherry using autopot is 61.73 kg.m^{-3} ; so water harvesting system could be an alternative appropriate technology to supply irrigation on red oval cherry tomato production; especially in farmer's land.

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