# Asian Journal of Plant Sciences

ISSN 1682-3974

OPEN ACCESS Asian Journal of Plant Sciences

ISSN 1682-3974
DOI: 10.3923/ajps.2017.149.159

# Research Article
# Impact of Water Use on Paprika (*Capsicum annum*) by Using Fertigation and Autopot System Combined with Numerous Growing Media

Nurpilihan Bafdal, Sophia Dwiratna and Dwi Rustam Kendarto

Department of Agriculture Engineering, Universitas Padjadjaran Sumedang, 40600 West Java, Bandung, Indonesia

## Abstract
**Background and Objective:** In dry season crop tends to lack of water. The effort was done to supply water needed by plants instead of water loss through evapotranspiration (ET). Collected rainfall harvesting in the wet season is one of an alternative for irrigation resources. Self watering fertigation system using autopot could optimize the use of various growing media of paprika's plant. The study aimed to determine the impact of physical characteristic media to water use and paprika's yield. **Materials and Methods:** Investigation method used was descriptive analysis with three treatment of growing media namely husk charcoal and compost ($m_1$), husk charcoal and humus ($m_2$) and husk charcoal and cocopeat ($m_3$) **Results:** The results showed the highest paprika's yield found in the growing media of husk charcoal and humus ($m_2$) as many as 1.32 kg per plant. The reasoning due to the growing media of husk charcoal and humus be able to optimize the paprika's yield. Water use by paprika plant in one cropping period of 488.18 or 17.435 L per plant. **Conclusion:** It was concluded that the combination of husk charcoal and humus is the best growing media for paprika cultivated by using fertigation and autopot system.

Key words: Growing media's, autopot, self-watering fertigation system, crop water use, rainfall harvesting

Received: May 04, 2017 Accepted: June 01, 2017 Published: June 15, 2017

Citation: Nurpilihan Bafdal, Sophia Dwiratna and Dwi Rustam Kendarto, 2017. Impact of water use on paprika (*Capsicum annum*) by using fertigation and autopot system combined with numerous growing media. Asian J. Plant Sci., 16: 149-159.

Corresponding Author: Nurpilihan Bafdal, Laboratory of Soil and Water Engineering, Department of Agriculture Engineering, Faculty of Agricultural Industrial Technology, Universitas Padjadjaran, 40600 West Java, Indonesia Tel: +62 816 614 823



Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Indonesia climate has two seasons: A wet season and dry season. During the dry season, crop is lacked of water, in contrary, the rain water often causes flood in agriculture land. The alternative to solve this problem, it was created an appropriate technology such as to harvest rainfall during the wet season and applied it as irrigation to the crops[1,2]. Rainwater harvesting is conducted to support the performance of irrigation methods that aims to provide water to plants as the substitute of crop's water needs that lost due to evapotranspiration (ET). Rainfall harvesting in Indonesia is one of innovation or technology that it is cheap enough since it does not require high cost, eco-friendly and the appropriate technology could be–adopted by farmers in the rural and urban areas[3-5]. At the moment, Goyal[6] reported that there have been many studies done on the performance of irrigation methods for plants but still using high electrical energy.

The technologies can optimize the use of rainwater which is available as irrigation and is currently being developed in Europe, Malaysia, Australia, and the United Kingdom[7]. Self-watering system technology can be applied in Indonesia by rural farmers as well as prepared in the context of urban agriculture. The self-watering system is a system of automatic water without the use of electricity and pumps, but it gives the results of the efficiently of water used[7,8]. The self-watering system can be utilized simultaneously with fertilizer called as a fertigation but should monitor pH and Electric Conductivity (EC). Ideally, the self-watering system applied by using the growing medium[3,8].

Various organic media investigated these are being a combination of (i) Husk charcoal with humus, (ii) Husk charcoal with cocopeat and (iii) Husk charcoal with compost. The selection of growing medias is based on the farmer's ease in getting it and the price is relatively low compared to other growing media such as rockwool[9,10]. The growing media were have been selected then mixed with a a 50:50 composition then put in the polybag and place it into the autopot. In these systems, the water get into the reservoir is controlled by using a smart-valve (Fig. 1).

Cultivation of paprika can be combined with self-watering irrigation system using the autopot and various growing media. Paprika plants that are grown are more difficult than the cayenne pepper, red chilli and curly red pepper. With intensive care, one plant of paprika growing in hydroponic systems can produce a 1.5-2 kg per plant, should it be planted in the soil, it only produces 1 kg per plant. In that case, the value of the economic feasibility of the paprika grown in hydroponics is more favourable than planted in the soil. Based on the research data of the Centre of Statistic Indonesia; the paprika has a stable and large export volume to some countries such as Taiwan, Malaysia and Singapore[11]. According to General Directorate of Horticulture Ministry of Agriculture Indonesia[11], at the beginning of July until mid-2013, the export volume amounted to 7,085.166 kg of paprika it means that the paprika have a bright prospect for domestic and abroad market.

(a)

(b)

Fig. 1: Single and double tray autopot with smart-valve

The concentration of nutrients highly determines the successfulness of paprika cultivation in hydroponics. Hydroponic farmers in the Netherlands always change the concentration of nutrients which is regularly adapted to the local environment and plant varieties. The investigation used mixed nutrition which is a readymade nutrient for different types of plants, density or concentration of nutrients. These need to be adapted to the climate, region, varietal and media. The concentration of nutrients cannot be standardized or equated. Based on some problems above, such as limited water in dry season, the combination of organic media and paprika's yield, the study aimed to determine the impact of physical characteristic of growing media and fertigation using autopot system on water use and yield of paprika.

## MATERIAL AND METHODS

**Research location:** This research was carried out in 2016 and 2017 located in the greenhouse of Padjadjaran University, Jatinangor Campus. The location of the study is on 6°48' LS and 107°21' BT with an elevation of 753.96 m a.s.l. with an average temperature of 10-20°C and humidity of 85-89%. The research method is descriptive analysis method, i.e., analyzing data quantitatively and investigating the link between the physical characteristics of the planting medium effecting on water consumptive use and the results of paprika production (*Capsicum annum*).

- The study of literature, the stage of the preparations done firstly is looking for a broad range of research related to paprika plant, rain harvesting, supply and demand, water management, self-watering system, fertigation and physical characteristics of the media for planting
- Calculation of the rainfall collection conducted in the wet season so that the rain harvesting as a water supply in the dry season can be met, the main irrigation network and device self-watering fertigation system
- Planting paprika, firstly conducted seed bed of paprika plants during 26 days or until the number of leaves growing 4-5 pieces then the seedlings can be planted into polybags and put it in the autopot. The planting media determination is done by way of mixing two different kinds of media in a polybag, i.e., husk charcoal and compost, husk charcoal and humus and husk charcoal and cocopeat with the composition of 50:50% based on the autopot volume. Paprika is planted using the media that has been mixed and then put in autopot, with 28 plants for 14 autopots

**Research observations:** The variables observed in this study are as follows:

- Measurements of microclimate included were daily temperature, humidity, the intensity of the sunlight and evaporation in the greenhouse. Measurement of the intensity of the sun is conductedevery day at 7.00, 12.00 and 17.00 until the harvest. The humidity and temperature of the greenhouse measured using thermo-hygrometer and the evaporation observe using evaporation pan class A
- Measurements of electrical conductivity, a pH, temperature and salt level of the nutrient solution is done by using water quality probe
- Physical characteristics of growth media composition including moisture content, bulk density, the weight of the total pore space, type, drainage, permeability, water available, moisture content with pF by 1; 2; 2.54 and 4.2
- Calculation of the volume of rainfall harvesting as an irrigation water resources accommodated to plant paprika. Calculation of the amount of rainfall harvesting accommodated daily at the moment before the rain (SB) and after rain (SH). It aims to find out if the number of cached volume of water can meet the water used on paprika
- Calculation of water consumption where is the total amount of water that is absorbed by plants. The number of increasing use of water for plant growth that must be met by the irrigation water, affected by plant type, the intensity of the sunlight, irrigation systems, length growth, rain and other factors[12,13]. Water use was calculated each day by the number of plant paprika, to get the value of the use of water the plant every day using the Eq. 1[14,15]:

$$\text{Water use} = \frac{\text{No.of daily waterloss (L)}}{\text{No.of plants}} \quad (1)$$

From the results of the value of the use of water the plant every day, then calculate the value plant water usage every month in order to know the total water use for each planting media per month

- The calculation of the value of the ETo, Kc and ETc. Calculations ETc is done in three step, the first search ETo in advance usesthe method of evaporating pan, using the Eq. 2[13]:

$$\text{Eto} = \text{Kp} \times \text{Ep} \quad (2)$$

Where:
Eto = Evapotranspiration potential (mm day$^{-1}$)
Kp = Pan coefficient 0.8 (Class A)
Ep = Evaporating pan (mm day$^{-1}$)

The second step, after the calculation of the value of the ETo, was the value of Kc, in whichKc is a crop coefficient that states the relationship between ETo and ET plants. The value of Kc's diverses plant types and corresponds to a phase of growth, to get the value of Kc,usethe Eq. 3[12]:

$$Kc_i = Kc_{prev} + \left(\frac{i - \sum(Lprev)}{Lstage}\right) \times \left(Kc_{next} - Kc_{prev}\right) \quad (3)$$

Where:

- I = Today on the growth phase
- $Kc_i$ = Coefficient of plant on this day
- $L_{stage}$ = Old growth on the phase
- $\sum (L_{prev})$ = The number of days before the phase
- $Kc_{next}$ = Coefficient of plant on the next phase
- $Kc_{prev}$ = Coefficient of plant on the previous phases

From the results of the value of the ETo and Kc, it can be counted the number of plant's consumptive water needs by using the Eq. 4[12,16,17]:

$$Etc = Eto \times Kc \quad (4)$$

Where:

- Etc = Evapotranspiration plant (mm $day^{-1}$)
- Eto = Evapotranspiration potential (mm $day^{-1}$)
- Kc = Coefficient of plant

- Observation of the paprika plant growth parameters is by looking through the plant growth including the height of paprika, number of leaves, the number of fruit, fruit circumference and fruit weight. Height measurement of the plant and the number of leaves are implemented once a week until flowering having been fruitful, calculate the number of fruit and measure the circumference of the fruit once a week; then the measurement of fruit weights were done after the harvest. Measurement of the paprika's weight aims to find out the results of the production of paprika in each media. According to Bafdal[3], the yield of paprika per hectare can calculate by using Eq. 5:

$$\text{Production per hectare} = \text{The production of paprika each media} \times \text{number of plants per hectare} \quad (5)$$

## RESULTS AND DISCUSSION

The results showed that the harvested rainfall is ableand sufficient to serve as a source of irrigation water during the dry season. The use of several types of organic growing media in the autopot fertigation system shows different paprika results. The highest yields were obtained on the growing media of husk charcoal and humus. In contrast to the research reported by Bafdal[3] that the use growing media of husk charcoal+compost on autopot fertigation system gives higher yields on cherry tomato.

**Suitability of microclimate:** Microclimate influences the growth of paprika plants including temperature, humidity and the intensity of the sunlight. Each plant requires a particular temperature range for growth well. Too high or too low temperature in greenhouse has worse effect towards the growth of plants. If the temperature is too high, the plant will lose a lot of fluids due to evaporation. This causes the plant look like a dead leaf tissue that is burned up and eventually, the entire plant dies. Otherwise, too low temperature will cause necrosis of tissue of lamina of the leaf therefore the leaves fall then the plants stunted its growth.

Temperature also affects metabolic processes of plants i.e., affecting production (the process of the formation of the fruit). Too high or low temperature is, will cause a decline in fruit production and has small form. In addition it causes not so good germination seeds that produces improper seeds. To grow and produce well, paprika plant requires a temperature on 21-27°C during the day and 13-16°C at night.

The paprika plant has a low tolerance towards the outside temperature conditions. Paprika is still able to grow at a maximum temperature of 30°C, however, in the temperatures of 38°C during the day and 32°C at night, all the flowers and fruit will fall as reported by Katsoulas and Kittas[18]. In Indonesia, this plant fits to be planted in the highlands with 16-25°C. The average daily temperature is 30.2°C, with a mean minimum temperature 20.7°C and maximum temperature 39.7°C. According to Katsoulas and Kittas[18], the Solanaceae plant will grow optimally at temperatures of 25°C, temperatures in the greenhouse is too high for the growth of the paprika plant so that the paprika grow less well (dwarf plants) and some of the plants will experience a fall flower.

Paprika plants will grow well and produce high yield if a humidity is about 80%. The low humidity causes the plants suffer from chlorosis and antosianensis. Severe dryness can lead heading into withered fruits and leaves fall prematurely. Low humidity can also cause a die-back and flowers withered, so reproductive process gets stalled. Otherwise, too damp air can cause decay of the roots, so the plant's wilt. The root decay occurs due to the activity of boletus and bacteria attack then the roots are damaged. The utilization of nutrient elements in the media to make unbalanced, therefore the plant growth is impaired. Based on the average value of daily moisture mounting to 56.8%, then the air humidity in the greenhouse is too low, so the paprika grows less proper.

Other factors in order to plant proper paprika is by earning sufficient solar intensity throughout the day. Insufficient sunlight intensity will lead to stunted plant growth either generative or vegetative growth. The plant will be

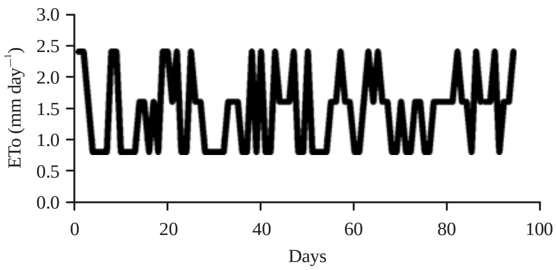


Fig. 2: Potential evapotranspiration (Eto)

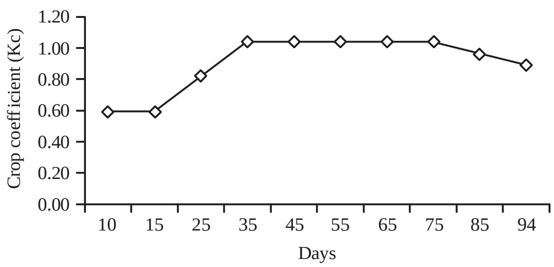


Fig. 3: Crop coefficient curve of paprika
Crop coeffiecient (Kc) is dimensionless coefficient

etiolating, thin, weak, easily falling, falling leaves and eventually dying so it cannot form the fruit. Otherwise, if too high sunlight intensity will make the plants ill. It is signed with disease namely leaf chlorosis, some tissues become brown and the fruit become dry. At the beginning of the growth and the impending adulthood, the paprika plant is grown in the greenhouse in order to obtain growth and establishment of maximum fruit yield. The intensity of the sunlight required ranges from 22-30% received by the whole plant. The average energy of the sun in the greenhouse is at 7.00 am with 7373 lux, at 12.00 with 35176 lux as well as at 17.00 with 2682 lux. Plants and the object will emit radiation waves of heat but the heat wave can't get out sinceit is absorbed and radiated back into the greenhouse. As a result, an increase in the temperature in the greenhouse is needed to overcome these problems by usingfogging irrigation from up of greenhouse. If the air temperature in the greenhouse hasalready entered a maximum at 30°C, then spray ignited and expected air temperature can drop.

**Calculation of the value ETo, Kc and ETc:** Evapotranspiration is the process of losing water out of a terrain of cultivation through evaporation and transpiration. Evaporation from the soil surface and transpiration from plants is difficult to separate so that both of them are called evapotranspiration. Almost all the water is absorbed by the plants from growing medium will undergo the process of transpiration and only a small part of the utilized crop[12,19-21]. Water use as consumptive use on paprika is the amount of water needed to replace the water lost due to evapotranspiration process during plant growth. The value that is used to obtain the value of the potential evapotranspiration using method of evaporation pan, value evapotranspiration potential (ETo) is shown in Fig. 2.

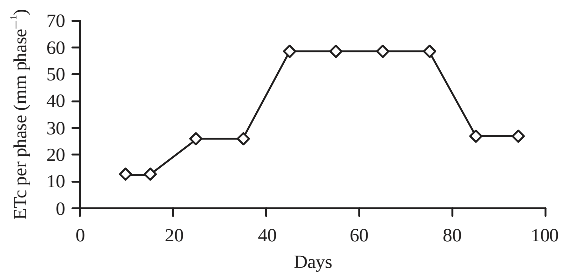


Fig. 4: Crop evapotranspiration of paprika (Etc)

The ETo values generated get increased and decreased each day since the value is different each day, as shown in Fig. 2. The value of potential evapotranspiration (ETo) for each phase of plant growth are 20.8 mm for initial period, 31.18 mm for development period, 56.0 mm for mid-season period and 27.81 mm for late season period. The total value of ETo is 135.79 mm. After getting the value of the potential evapotranspiration, the next step is finding crop coefficient (Kc) as illustrated in Fig. 3 follows:

The initial growth period occurs during the 15 days with a value of Kc of 0.6. The phases of development took place during the 20 days, on this phase value of Kc varies per decade during the decade 1 of 0.83 and in the decade 2 of 1.05. The mid-season phase occurs during the 40 days with a value Kc of 1.05; the phase of late-season happened during 19 days , in this period the value of Kc varies every decade: in decade 1 of 0.97 and the decade 2 of 0.9, as shown in Fig. 3. The highest value of Kc is found in the phase of mid-season because there is a transitional phase of the growth process of vegetative phase toward generative phase. On the phase of late season, plants need lots of water absorption of nutrients but less perfect for keeping fruit from rotting. Quantity value of Kc then could be used to determine the magnitude of the value of the evapotranspiration plant, for more details it is shown in Fig. 4.

The value of the water needs of crops produced each phase relates to the value of the crop coefficient, as shown in Fig. 3. The amount of the plant's water needs for each phase of plant growth is 12.48 mm for the initial period; phases of development is 25.88 mm, mid-season phase is 58.8 mm and 26.98 mm for the late-season stage. The value of potential ETc is of 124.14 mm per one cropping period, while the actual ETc is 91.56 mm day$^{-1}$ period of cropping. The value of the

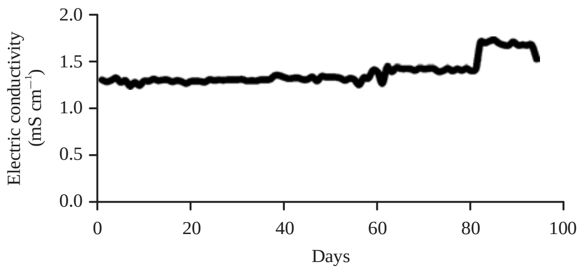


Fig. 5: Electric Conductivity (EC) of nutrient solution

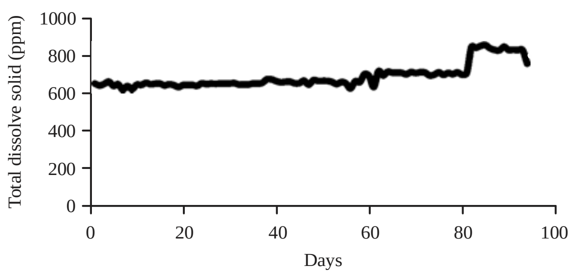


Fig. 6: Total Dissolve Solid (TDS) of nutrient solution

actual ETc obtained is smaller than the value of the potential gap ETc of 32.58 mm per cropping period. It is caused by the growth of the paprika plant is not uniformed and less optimal. The factor that affects the value of the evapotranspiration is the temperature in the greenhouse. The temperature was higher in the greenhouse, the greater the evapotranspiration value. Otherwise, the temperature was lower in the greenhouse, the smaller the evapotranspiration value. The lowest process of evapotranspiration occurred during the rainy season.

**Observations of the nutrient solution:** On the self-watering system, watering is done in conjunction with fertigation. Treeby *et al.*[22] reported that the advantages of supplying mineral nutrient to crop root using fertigation include: (i) Reduced delivery cost, (ii) Greater control over where and when nutrient are delivered leading to greater fertilizer use efficiency, (iii) More control over crop behavior and (iv) Potential for reduced fertiliser losses. In the management of fertigation, there are several factors to consider, namely Electrical Conductivity (EC), pH, DO, temperature and salt levels in an aqueous solution. The primary key in the granting of nutrient solution on the self-watering system is control the value of Electrical Conductivity (EC) or the flow of electric in the nutrient solution. Good electrical conductivity values to the paprika plant growth of 1.8-2.2 mS cm$^{-1}$ as reported by Wortman[23]. Every stage of growth of plants needs a varies EC solution. EC needs with customized phase growth when the plants are still small. The more increasing age of the plant, the bigger the EC.

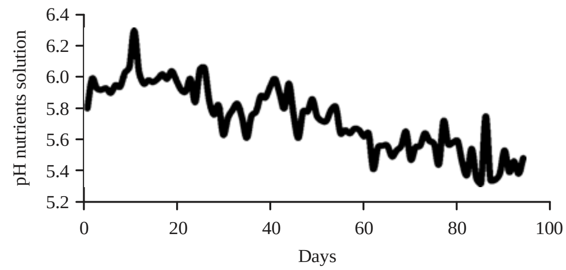


Fig. 7: Degree of acidity (pH) nutrient solution

Suzuki *et al.*[24] reported that the requirements of the EC is also influenced by the condition of microclimates such as temperature, humidity and evaporation on the greenhouse. The low temperature in the greenhouse, it is recommended to adjust high and low EC. The more some dissolved ions, the higher the nutrient solution EC. High to low in a nutrient solution EC affecting the metabolism of plants are photosynthesis of high plant, enzyme activity and potential solutions of ions absorption by plant roots. The value of high EC can cause shorter harvest age, increasing levels of fruit sugar and less freshness. The EC also effects on resistance to the attacks of the disease. In general, the value of EC 4.6 mS cm$^{-1}$ is the EC threshold of a solution. EC that exceeds the limits will damage the crops. The value of the Electric Conductivity (EC) paprika plant nutrient solution is shown in Fig. 5.

The resulting EC amounting to 1.24-1.72 mS cm$^{-1}$ points out that the EC value is too small, preferably in solution nutrients in add with extras such as fertilizer addition of elements N, P and K from the EC value that is observed, then it is calculated as shown in Fig. 5. The value of Total Dissolve Solid (TDS) paprika plant nutrient solution shown in Fig. 6 as follows:

The resulting TDS is 621-859 ppm, to plant peppers the value of TDS should be 1260-1540 ppm, it indicates that the value should be higher in EC nutrients since the higher value of the EC, the higher the TDS value resulting nutrient solution as shown in Fig. 6. In addition to the EC, pH is also an important factor to be controlled in a nutrient solution. The different nutrient formula has a different pH because fertilizer salts have various levels if dissolved in water. Controlling the pH of the nutrient solution should be done due to the absorption of nutrient elements. In order to get good results, the pH of the solution recommended for paprika crops ranges between 6.0-6.5. The degree of acidity (pH) of paprika plant nutrient solution shown in Fig. 7.

The value of the pH of the nutrient solution produced by nutrient is 5.3-6.3, it shows that nutrient solution has been used by the literature so that the ions in solution can be

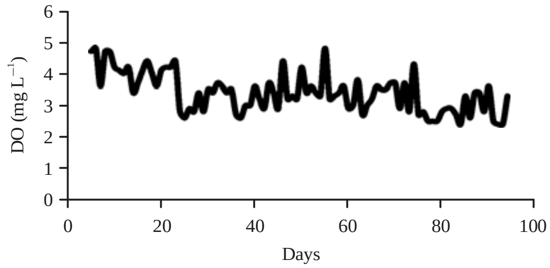


Fig. 8: Dissolved Oxygen (DO) nutrient solution

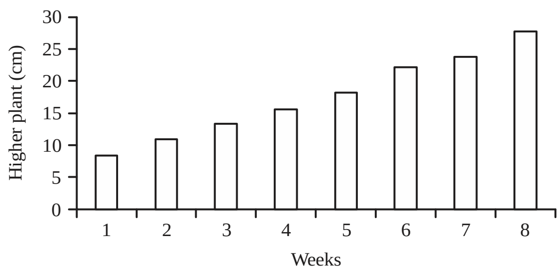


Fig. 9: Paprika plant growth

absorbed by plants as illustrated in Fig. 7. Maintaining the proper pH of the nutrient solution is crucial in order to not cause a blockage in the system of self-watering funnel fertigation.

Dissolved Oxygen (DO) is required and safeguarded in nutrient solution stability so that respiration can occur in roots when low levels of oxygen in the root zone so the roots don't take the nutrients needed for growth. Low oxygen levels cause an increase in the production of ethylene at the roots if high levels of ethylene in the root then the roots start hematoma and died. The more oxygen, the better nutrient absorption and the root system will be. The optimal level oxygen to the plant that is as big as 7-9 mg $L^{-1}$ of Dissolved Oxygen (DO) values of the paprika plant nutrient solution shown in Fig. 8.

The DO values of the nutrient solution shows that the concentration of oxygen is not optimal and then it causes plant roots grow improperly, as shown in Fig. 8. The levels of salt solution (salt) in the nutrient solution are observed amounting to 0.07-0.09. The value of the levels of salt is good enough for plant growth. High salt levels can impede the process of photosynthesis in plants. Morphologically, high salt levels cause the plant no longer able to absorb water in the rooting area. Decreased water absorption by the roots causes the disruption of plant growth with the symptoms such as lack of water (wilt). The value of electrical conductivity (EC), pH, Total Dissolve Salt (TDS), Dissolved Oxygen (DO) and the levels of salt in a solution deeply effect on plant growth and sweet chilly paprika yield.

**Observations of paprika plant growth:** Observations of plant growth are carried out once a week to find out the paprika plant growth each week. Plant paprika seeds to propagate from paprika seeds for 26 days or until the number of leaves growing 4-5 pieces and then the seedlings can be moved into the polybags before putting it in the autopot. Based on field observation, this phase of the paprika vegetative plant is going for five weeks, in the first week of March, the plant has begun to appear interest obviously. The paprika plant growth can be seen in Fig. 9.

Based on Fig. 9, from the 1st week to the 8th week, the higher plants have increased, this means the plants grow quite well. In addition to the height of plants, the leaves should be calculated in order to find out its growth. The number of leaves on a plant is relatively a lot, so some plants look lush but in every week the number of leaves is reducing since the temperature is high enough that makes the leaf fall in greenhouse.

The dead plants in their early growth can be embroidered on the second week using the new seeds, so that it can continue to grow properly. In one autopot, there are two growing plants. For example, growing paprika using media of husk charcoal and humus ($m_2$) in the first pot and second pot become uniform even though the nutrition given is converted at both the similar composition plants. During the paprika plant growth, they experience constraints stricken with pests and diseases.

In the paprika generative phase is also carried out the observation of itinerant fruit number. It is done to determine whether the use of the nutrients are absorbed by the plant nutrient as wellas possible if the plants absorb nutrients properly then the circumference of the fruit every week will be even greater and the number of fruit to be generated more and more each week. Each paprika plant has a different harvest time. The greater the circumference of the fruit and the more fruit produced at the autopot then the better the nutrients are absorbed by the plant.

Other factors that affect plant growth media, namely organic planting bell paprika used, each cultivation media has value C/N ratio. Growing media of the husk charcoal and compost ($m_1$) as well growing media of husk charcoal and humus ($m_2$) showed increasing growth every week. The value of C/N ratio compost by 17 and the C/N ratio of the humus of 13. The value of C/N ratio on compost and humus is approaching the value soil C/N ratio ranging between 10-12. So the plant growth showed good result because if organic ingredients have the ratio C/N approaching or equal to soil C/N ratio, then the organic material can be used for plant growth. It looks different in the growing media with husk

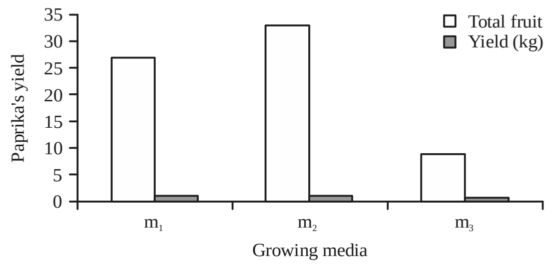


Fig. 10: Paprika's yields of each growing media (kg)

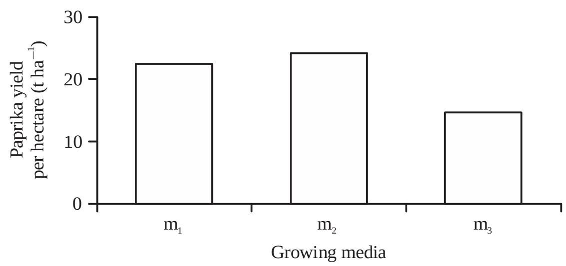


Fig. 11: Paprika's yield of each growing media per hectare

charcoal and cocopeat ($m_3$) the growth is stunted because the media $m_3$ has a high water content and cause the root could not be developed due to lack of oxygen. Such longer and submerged root condition makes the roots cannot absorb nutrient elements correctly. Immature cocopeat contains tannins that can inhibit plant growth. Cocopeat has C/N value ratio of 72 as reported by Awang *et al.*[25]. In General, fresh organic ingredients have high C/N ratio[10,26]. The value of C/N affects the ability of organic matter to absorb the nutrient elements, the higher the value of the C/N, the slower increasing the ability of organic matter absorb the nutrient. This growth in such media is blocked.

**Paprika's yields:** The quality of the harvest paprika is mainly determined by handling the harvest and post-harvest handling. Paprika can be collected at the time of green or red ripening. A mature green bell paprika fruit is suitable for consumption as a vegetable because it has a sweet taste without the nutty taste. Red paprika is less good to be consumed as a vegetable because it has a slightly nutty taste. Picking the paprika fruit should not be done at the time the fruit is too ripe or too young. The too ripe fruit will fall by itself and in general fruit condition already ugly. Picking is conductedon time the fruit contains substance, with weights that are already pretty heavy. A good time to harvest the fruit of capsicum is in the morning or evening, when the weather is nice (no rain) and no heat. Thus, the paprika harvested fruit will not experience the ravages of inclement weather. There are calculation results of each bell paprika production media.

Table 1: Volume of rain water accommodated

| Months | Volume accommodated (L) |
|---|---|
| January | 3,329.10 |
| February | 8,425.20 |
| March | 15,141.02 |
| April | 4,400.00 |
| May | 646.18 |
| Total | 31,941.50 |

The observations of the yields of paprika each growing media (kg) shown in Fig. 10 as follows. Paprika yields, produced inhusk charcoal and humus growing media ($m_2$) amounting to 1.32 kg per plant with a whole fruit of 33 as shown in Fig. 10.

Growing media of husk charcoal and compost ($m_1$) produces 1.22 kg per plant, the growing media husk charcoal and cocopeat ($m_3$) produces the lowest paprika i.e., 0.81 kg per plant. The reasoning is cocopeat still immature so astringent tannins contained in the cocopeat become toxic to paprika plant. The results from the yields of paprika per kilogram can be calculated from any media with a unit of tons per hectare which is shown in Fig. 11.

The highest paprika plant production is generated by a growing media of husk charcoal and humus ($m_2$) as many as 24.27 t ha$^{-1}$ as shown in Fig. 10. In one hectare there are 18,400 plants in which one plant produce 1.5 kg of paprika, therefore totally it yields paprika as many as 27,600 kg ha$^{-1}$ or 27.6 t ha$^{-1}$ in which the yield is lower than the actual yield theoretically i.e., 30 t ha$^{-1}$. The other factors influencing the results of the lower yield of paprika is the number of harvesting only 3 (three) times while the optimal growing paprika should be able to harvest 5-6 times.

**Crop water use:** The availability of high-quality water is crucial to support the success of the process of paprika cultivation. The ways that can be done to provide water as a source of irrigation water in the dry season is to makea rainfall harvesting. Source of irrigation water should be enough to be absorbed into the plant so that plant grows optimally. On (Table 1) provided data on the total volume of rainwater of cached 31,941.5 L whereas the use of the water needed to plant paprika in one period of planting of 488.18 L for 28 plants.

With the rest of the cached rainwater as much as 31,453.32 L, therefore there is no reason not to plant paprika during the dry season because of the availability of adequate water for planting paprika. Table 1 shows the volume of rainwater cached.

From the results of the cached water volume then the used rain was calculated so that each media circulate in and out the amount of water used. Calculation of the water use of paprika uses data percentage of moisture content

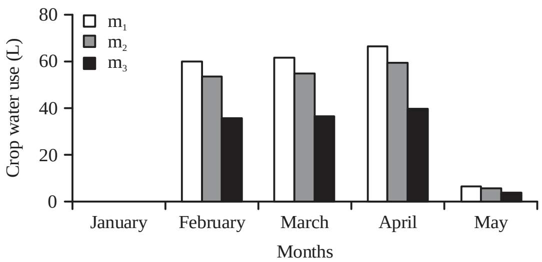


Fig. 12: Crop water use per month

Table 2: Percentage of moisture content on mixed media

| Media | Moisture content (%) | Difference in moisture content (%) |
|---|---|---|
| $m_1$ | 54.9 | 45.1 |
| $m_2$ | 59.8 | 40.2 |
| $m_3$ | 73.1 | 26.9 |
| Total | | 112.2 |

Table 3: Moisture content on various media

| | Moisture content (% volume) | | | |
|---|---|---|---|---|
| Media | pF* 1 | pF 2 | pF 2.54 | pF 4.2 |
| m1 | 51.3 | 44.0 | 38.3 | 17.0 |
| m2 | 52.5 | 40.0 | 34.6 | 15.9 |
| m3 | 63.7 | 34.3 | 29.5 | 13.8 |

*pF is logarithm of the negative hydrostatic head (cm), in equilibrium with a sample of moisture content

on any media, such data are indicated by Table 2. The percentage of moisture content on growing media then it can be calculated the water usage per month on the paprika plant as illustrated in Fig. 12.

The most water use in April amounted to 166.4 L because this month start entering the process of ripening fruit which a plant needs water much more compared to the previous month. For instance, in February, it needs 150.04 L and March is 154.04 L as shown in Fig. 12. The reason is because in the beginning and towards the end of the growth of the plant requires minimum water, while in flowering requires maximum water. It corresponds to the reality in the field. Water use in May is the fewest as much as 17.7 L, this is because toward the end of plant growth.

**Impact of the physical characteristics of the planting media with water use and yield production of paprika:** Planting media types used truly effect on growth, development and yield of plant production. Barrett *et al.*[27] reported that soilless cultivation is recognized globally for its ability to support efficient and intensive plant production. The media used must be able to provide water, nutrient and oxygen as well as the substance which does medium paprika not contains toxic to plants. The weighting of the data content, type and weight of the total pore space has a link between one and the other. The value of bulk density on husk charcoal and compost ($m_1$) is 0.53 g/cc and particle density is 1.71 g/cc. The valueis higher than growing media of husk charcoal and humus ($m_2$) with a value of bulk density 0.46 g/cc and the particle density is 1.62 g/cc . The other hand, on growing media of husk charcoal and cocopeat ($m_3$) have characteristic of bulk density of 0.21 g/cc and particle density of 1.48 g/cc. It should be a growing media of husk charcoal and compost ($m_1$) that has a higher production because the amount of solids to absorb nutrients thermally in $m_1$ but to plant paprika media with greater bulk density, it will be hard to pass on the water. Then the plant has the highest medium paprika productivity that uses media with a mixture of husk charcoal and humus ($m_2$). The total pore space, the total number of pores in porous media, or the free space filled with water. The value of the total pore space in the growing media of husk charcoal and compost ($m_1$) is 69.3% lower than the growing media of husk charcoal and humus ($m_2$) 71.6% and the growing media of husk charcoal and cocopeat ($m_3$) for 85.6%. Plant growth will be optimal if it keeps water on the media, then it should be growing media of husk charcoal and compost ($m_1$) that is the best condition for plant growth, but the growth of the paprika plant is the best growing media that is a growing media of husk charcoal and humus ($m_2$).

From data pF or the value demonstrated pF 2, pF 2.54 and pF 4.2 growing media of husk charcoal and compost ($m_1$) is greater than the one with a growing media of husk charcoal and humus ($m_2$) and another growing media of husk charcoal and cocopeat ($m_3$). According to Oh *et al.*[28], the water content of the growing medium is dependent on composition of the medium. The values of the levels of each media can be seen in Table 3.

The availability of water in the growing media of husk charcoal and compost ($m_1$) is more than an organic media of husk charcoal and humus ($m_2$) and a growing media of husk charcoal and cocopeat ($m_3$) so that the effect on water use is better on the $m_1$. However, the highest production results contained on the growing media of husk charcoal and humus ($m_2$) that is not by the value of moisture content because paprika can grow optimally in growing media that contains humus. Soil water that lies between the field capacity (pF 2.54) and permanent wilting point (pF 4.2) is water that can be used by plants, called available water, any value derived from the difference between the two.

The quick drainage needs respirator's relationship with plant roots, hence the quick drainage should be maintained to be always filled the water if fast drainage pores over 10% of the volume of the crop will get sufficient aeration. The growing media have porous drainage as follows: 25.3% for husk charcoal and compost ($m_1$), 31.6% for husk charcoal and humus ($m_2$) and of 51.5% husk charcoal and cocopeat ($m_3$).

The study of impact of water use on paprika by using fertigation and autopot system combined with various growing mediawere highest implication for plant sciences especially in paprika with growing husk charcoal and compost media by using fertigation and autopot. The water used as an irrigation resource came from rainfall harvesting and be able to apply it as a water used during dry season and wet season. It means the resources of irrigation are available whole year. The Limitation of this study is still micro scale and needs another study in macro scale for example in outdoor research or in the field.

## CONCLUSION

Based on the research observation that has been conducted, it can be summed up as follows:

- The total volume of cached rainfall harvesting is 31,941.5 liters whereas the water use by the paprika plant in one cropping period of 488.18 or 17.435 L per plant
- Based on the physical characteristics of the organic media can be said that husk charcoal and humus to be optimal for paprika's growth
- The paprika's yield produced by a growing media of husk charcoal and humus is 1.32 kg per plant, whereas in an organic media of husk charcoal and compost is 1.22 kg per plant and as well in the growing media husk charcoal and cocopeat is 0.81 kg per plant

## SIGNIFICANCE STATEMENTS

This study discovers the rainwater harvesting as a source of irrigation on self-watering fertigation system using autopot that can be beneficial for paprika yield. The study will help the researcher to uncover the critical area of crop water use from rainwater harvesting and self-watering fertigation system by using autopot with numerous organic media that have not been explored by many scientists. Therefore, this is a new theory of using rainwater harvesting as a source of irrigation on self-watering fertigation system with various organic media.

## ACKNOWLEDGMENTS

The authors would like to thank to the Rector of Universitas Padjadjaran for the Academic Leadership Grant's funding, trough internal grant number 431/UN6.431/PL/2016.

## REFERENCES

1. Yosef, B.A. and D.K. Asmamaw, 2015. Rainwater harvesting: An option for dry land agriculture in arid and semi-arid Ethiopia. Int. J. Water Resour. Environ. Eng., 7: 17-28.
2. Oweis, T., A. Hachum and J. Kijne, 1999. Water harvesting and supplemental irrigation for improved water use efficiency in dry areas. SWIM Paper No. 7, Colombo, Sri Lanka.
3. Bafdal, N., 2015. Rainfall harvesting as resources of self watering fertigation system with various growing medias. Int. J. Adv. Sci. Eng. Inf. Technol., 6: 787-792.
4. Samuel, M.P. and A.C. Mathew, 2014. Improving water use efficiency by integrating fish culture and irrigation in coconut based farming system: A case study in Kasaragod District of Kerala (India). Int. J. Agric. Biol. Eng., 7: 36-44.
5. Contreras, S.M., T.S. Sandoval and S.Q. Tejada, 2013. Rainwater harvesting, its prospects and challenges in the uplands of Talugtog, Nueva Ecija, Philippines. Int. Soil Water Conserv. Res., 1: 56-67.
6. Goyal, M.R., 2014. Sustainble Micro Irrigation: Principle and Practice. CRC Press, Toronto, New Jersey, ISBN: 9781482246247, Pages: 506.
7. IRIS., 2015. IRIS autopot system. http://irisautopot.com.
8. Fah, J., 1996. Hydroponics Made Easy: A Useful Guide for Novice and Intermediate Users of Hydroponics. 2nd Edn., Agromatic Corporation Pty Ltd., Bayswater, Vic, ISBN: 9780646286617, Pages: 107.
9. Steiner, C. and T. Harttung, 2014. Biochar as a growing media additive and peat substitute. Solid Earth, 5: 995-999.
10. Carlile, W.R., C. Cattivello and P. Zaccheo, 2015. Organic growing media: Constituents and properties. Vadose Zone J., 14: 1-13.
11. Ministry of Agriculture Indonesia, 2015. Statistic of horticulture production year 2014. General Directorate of Horticulture. Ministry of Agriculture Indonesia, pp: 286.
12. Allen, R.G., L.S. Pereira, D. Raes and M. Smith, 1998. Crop evapotranspiration: Guidelines for computing crop requirements. FAO Irrigation and Drainage Paper No. 56, Rome.
13. Fisher, J.B., T.A. De Biase, Y. Qi, M. Mu and A.H. Goldstein, 2005. Evapotranspiration models compared on a Sierra Nevada forest ecosystem. Environ. Model. Software, 20: 783-796.

14. Sari, D.K., I.H. Ismullah, W.N. Sulasdi and A.B. Harto, 2013. Estimation of water consumption of lowland rice in tropical area based on heterogeneous cropping calendar using remote sensing technology. Procedia Environ. Sci., 17: 298-307.
15. Pfister, S. and P. Bayer, 2014. Monthly water stress: Spatially and temporally explicit consumptive water footprint of global crop production. J. Cleaner Prod., 73: 52-62.
16. Bouraima, A.K., Z. Weihua and W. Chaofu, 2015. Irrigation water requirements of rice using Cropwat model in Northern Benin. Int. J. Agric. Biol. Eng., 8: 58-64.
17. Wenting, H., X. Zhiqing, Z. Yang, C. Pei, C. Xiangwei and S.K. Ooi, 2014. Real-time remote monitoring system for crop water requirement information. Int. J. Agric. Biol. Eng., 7: 37-46.
18. Katsoulas, N. and C. Kittas, 2008. Impact of greenhouse microclimate on plant growth and development with special reference to the Solanaceae. Eur. J. Plant Sci. Biotechnol., 2: 31-44.
19. Zhao, L., J. Xia, C.Y. Xu, Z. Wang, L. Sobkowiak and C. Long, 2013. Evapotranspiration estimation methods in hydrological models. J. Geog. Sci., 23: 359-369.
20. Oweis, T.Y., H.J. Farahani and A.Y. Hachum, 2011. Evapotranspiration and water use of full and deficit irrigated cotton in the Mediterranean environment in northern Syria. Agric. Water Manage., 98: 1239-1248.
21. Eagleman, J.R., 1967. Pan evaporation, potential and actual evapotranspiration. J. Applied Meteorol., 6: 482-488.
22. Treeby, M., S. Falivene and M. Skewes, 2011. Fertigation: Delivering fertiliser in the irrigation water. Primefact 1089, February 2011.
23. Wortman, S.E., 2015. Crop physiological response to nutrient solution electrical conductivity and pH in an ebb-and-flow hydroponic system. Sci. Hortic., 194: 34-42.
24. Suzuki, M., H. Umeda, S. Matsuo, Y. Kawasaki, D. Ahn, H. Hamamoto and Y. Iwasaki, 2015. Effects of relative humidity and nutrient supply on growth and nutrient uptake in greenhouse tomato production. Sci. Hortic., 187: 44-49.
25. Awang, Y., A.S. Shaharom, R.B. Mohamad and A. Selamat, 2009. Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of *Celosia cristata*. Am. J. Agric. Biol. Sci., 4: 63-71.
26. Liopa-Tsakalidi, A., P. Barouchas and G. Salahas, 2015. Response of zucchini to the electrical conductivity of the nutrient solution in hydroponic cultivation. Agric. Agric. Sci. Procedia, 4: 459-462.
27. Barrett, G.E., P.D. Alexander, J.S. Robinson and N.C. Bragg, 2016. Achieving environmentally sustainable growing media for soilless plant cultivation systems-A review. Sci. Hortic., 212: 220-234.
28. Oh, M.M., Y.Y. Cho, K.S. Kim and J.E. Son, 2007. Comparisons of water content of growing media and growth of potted kalanchoe among nutrient-flow wick culture and other irrigation systems. HortTechnology, 17: 62-66.