Water efficiency and eggplant (*Solanum melongena L.*) growth with size pottery irrigation in Alfisols and Entisols

Rahayu2*, H Aktavia2, H S Fabian1, Komariah2

1Graduate School of Soil Science, Faculty of Agriculture Sebelas Maret University, Ir. Sutami Street 36A, 57126, Jebres, Surakarta, Central Java, Indonesia
2Department of Soil Science, Faculty of Agriculture, Sebelas Maret University, Ir. Sutami Street 36A, 57126, Jebres, Surakarta, Central Java, Indonesia
*Corresponding author: rahayu_uns@yahoo.com

Abstract. Climate change sues more effects in irrigation water management. The dry season is a major problem for the cultivation of rainfed crops. Subsurface irrigation with pottery potentially as a way out for rainfed crop cultivation. This study aims to determine the size and origin of pottery which has a high level of irrigation efficiency. This research is a pot experiment with pottery irrigation treatment with water seeping out of the pot into the soil efficiency and to obtain the size of the irrigation pot and the original material that is effective as a water pottery. Purple eggplant (*Solanum melongena L.*) was planted in Alfisols and Entisols soil in pots with a diameter of 60 cm and irrigation with pottery. The potteries were buried in the soil in the planting media, and the water was filled through the neck of the pottery and the volume measured every day as consumption of irrigation. The pottery used is from the center of the pottery Industry in Java, namely Bayat and Kasongan, with a volume of 7 liters and a small 3 liters. Result showed that the 3 liters size of pottery Kasongan produced more fruit than other treatment in Alfisols and efficient irrigation in Entisols than other pottery. The 3 liters pottery size is more water efficient and has better plant yield than a 7 liter pot.

1. Introduction
Climate change has consequences on average temperature as well as climate stability. The dry season is a climate change which is a major problem in the cultivation of rainfed crops. Climate variability and climate change has become a serious concern and could have adverse impacts on global food production and food security [1]. Rainfall is very important in providing water in rainfed and dry land. The higher evapotranspiration due to temperature increase causes a higher amount of water for irrigation [2]. Lack of water causes plants not to grow optimally and to reduce fruit production, because water is a component of 85-90% of fresh weight and plant tissue [3]. Therefore, there is a need for technical efforts to conserve irrigation water.

There are various ways to apply irrigation. To increase crop productivity and efficiency in the use of irrigation water, an effective and efficient application of irrigation management technology is required [4]. One of the irrigation techniques that have a high level of water use efficiency is subsurface irrigation. Subsurface is an irrigation technique that has a higher level of water use efficiency compared to surface irrigation [5]. Subsurface irrigation channels water directly to the root zone in plants, and plants take advantage of soil moisture which transfers to the root area which is driven by capillary forces. Subsurface irrigation with pottery has the potential as a solution for the cultivation of rainfed crops. Using pottery irrigation for planting bottle gourds using fresh and salty water showed 82-84% of water can be saved when compared to using conventional irrigation [6]. Pottery irrigation method can save
57.1% and 42.0% more water compared to the two-axis irrigation [7]. Irrigating pottery using pottery or a jug, the way it works is to put water into the pottery and the water will seep out through the walls of the pottery. This study aims to determine the size and characteristics of the most water-efficient pottery material for plants.

2. Materials and method

This research was a potted experiment in a vinyl house during the dry season from June to October 2019 at the Experimental Garden of the Faculty of Agriculture, UNS. The experimental design was completely randomized block design with 3 treatment factors, namely pottery size, pottery origin and soil type of growing media. The size of the pottery volume was: U1 = large size (volume = 7 liters); U2 = small size (volume = 3 liters). The origins of the pottery were: J1 = Bayat; J2 = Kasongan. Soil types for growing media were: T1=Alfisols; J2= Entisols. The treatment combination became 8, namely: U1J1T1; U2J1T1; U1J2T1; U2J2T1; U1J1T2; U2J1T2; U1J2T2; U2J2T2. Each combination was repeated three times so that it became 24 units. Follow-up tests used the Tukey Test with a confidence level of 95%. In this experiment, the soil used as a growing medium was alpha and entisol. Alfisol soil used has the following characteristics: pH=6.13, organic C=0.46%, N-total=0.07%, P available=7.07 ppm, and K available=5.02 ppm. The entisol soil used has the following characteristics: pH=6.7, organic C=0.95%, N-total=0.18%, P available=8.18 ppm, and K available=11.13 ppm.

Pots for planting containers use plastic pots with a diameter of 60 cm and a height of 30 cm. The pottery comes from the center of the pottery industry near Sebelas Maret University, namely Bayat Klaten and Kasongan Bantul. The characteristics of the pottery materials are presented in Table 1. The design of pots and pottery drawings was presented in Figure 1. The bottom of the pottery was coated with impermeable material so that water only seeps to the side. The pottery that was ready then placed in the center of the pot. Then the pot is filled again, leaving the potter's lip on the soil surface.

Figure 1. Placement of the pottery in the experimental pot

Eggplant seeds (*Solanum melongena L.*) were planted in polybags, and after 3 weeks the eggplant seeds were transferred to the planting pot. Irrigation was done by putting water into the pottery when the water runs out of the pottery. The pottery was refilled every ¾ of water is used up with the filling time based on the presence of water in the pottery. The amount of irrigation water added was measured by volume. Soil humidity was measured every day using a Digital Soil Moisture Meter and Soil Tester. Plant observations include plant height and crop yield. The soil media were analysed for the physical and chemical properties of the soil, including pH, texture, C-organic, moisture content, and porosity.
3. Result and discussion

Table 1. Characteristics of pottery materials.

| Pottery origin | COLE value | Status | Texture (%) | Status |
|----------------|------------|--------|-------------|--------|
| Bayat          | 0.000      | low    | 64.354      | silt   |
| Kasongan       | 0.072      | high   | 47.340      | clay   |

Source: Laboratory analysis of soil physics and chemistry, Faculty of Agriculture, UNS

Analysis of the Bayat pottery material has a dusty clay texture with a low COLE value. Kasongan material has a clay texture with a high COLE value. The COLE value determines the wrinkling of the earthen pottery. The clay type in the Bayat Hills is kaolinite and smectite and there are fragments of quartzite of various sizes so that they are not uniform and cause cracks in the pottery after drying and burning. Kasongan pottery shows a brick red color and does not show any cracks and fragments [8].

Table 2. The amount of water seepage on the pottery before being put into the pot for planting media

| Treatment | Volume water seepage (l/minute) |
|-----------|----------------------------------|
| Origin    | Pottery size | at 30 minutes | at 60 minutes | at 90 minutes | at 120 minutes | at 150 minutes |
| Bayat     | Big          | 1.03a         | 1.05a         | 0.35a         | 0.19a         | 0.19a          |
|           | Small        | 0.65b         | 0.31ab        | 0.48a         | 0.04a         | 0.01a          |
| Kasongan  | Big          | 0.90a         | 0.81ab        | 0.15a         | 0.26a         | 0.06a          |
|           | Small        | 0.53b         | 0.22b         | 0.07a         | 0.03a         | 0.03a          |

Mean in column followed by same letter is not significantly different base on Tukey 0.05.

Prior to the research, trials were carried out on pottery seepage. The pottery is filled with water under the same conditions, then measurements are taken at 30-minute intervals. It can be seen that in the early minutes there was a high seepage of almost 1 liter. Then the seepage that comes out starts to decline. This is related to hydrostatic pressure. The greater the volume in the pottery, the higher the hydrostatic pressure.

Table 3. General water requirements for eggplant growth in the experimental locations based on Etc

| Growth stage | Time       | Kc  | Eto (mm/day) | Etc (mm/day) | Water requirement (l/day) | Water requirement total (l) |
|--------------|------------|-----|--------------|--------------|---------------------------|-----------------------------|
| Initial      | 23-31 Jul  | 0.45| 3.31         | 1.49         | 0.50                      | 4.47                        |
|              | 1-6 Aug    | 0.45| 3.78         | 1.70         | 0.57                      | 3.40                        |
|              | 7-31 Aug   | 0.75| 3.78         | 2.84         | 0.95                      | 23.65                       |
|              | 1-4 Sept   | 0.75| 4.23         | 3.17         | 1.06                      | 4.23                        |
|              | 5-30 Sept  | 1.15| 4.23         | 4.86         | 1.62                      | 42.20                       |
|              | 1-3 Oct    | 1.15| 4.56         | 5.24         | 1.75                      | 5.25                        |
|              | 4-23 Oct   | 0.8 | 4.56         | 3.65         | 1.22                      | 24.34                       |
| Total        |            |     |              |              |                           | 107.54                      |

Source: Daily Climate Data Lab. Agroclimatology Jumantono, Karanganyar

Water requirements are calculated according to the surface area of the land used. Based on the Table 3, it is known that the water needs of eggplant plants are different for each phase. In the early growth phase, eggplant needs less water to meet its needs. Then the need for water is increasing along with the
growth of eggplant plants. It is known that the total water demand during the three months of the research was 107.54 liters.

Table 4. The results of the Tukey test analysis of the treatment of the amount of seepage

| Treatment | Aug (lt) | Sept (lt) | Oct (lt) | Total (lt) |
|-----------|----------|-----------|----------|------------|
| T1 U1J1   | 28.19b   | 29.68bc   | 38.21bc  | 96.08bc    |
| U2J1      | 15.24b   | 15.90c    | 18.41c   | 49.55c     |
| U1J2      | 42.08b   | 27.15c    | 27.97c   | 97.19bc    |
| U2J2      | 38.31b   | 31.71bc   | 31.14c   | 101.16bc   |
| T2 U1J1   | 107.94a  | 78.96a    | 82.62a   | 269.52a    |
| U2J1      | 35.83b   | 29.88bc   | 30.01c   | 95.73bc    |
| U1J2      | 62.63ab  | 58.09ab   | 62.26ab  | 182.98ab   |
| U2J2      | 37.33b   | 28.78c    | 29.92c   | 96.03bc    |

Mean in column followed by same letter is not significantly different based on Tukey 0.05.

T1: Alfisols; T2: Entisols; U1J1: Bayat Besar (7 liters); U2J1: Bayat small (3 liters); U1J2: Kasongan Besar (7 liters); U2J2: Kasongan small (3 liters).

Based on the results of Tukey’s test, it is known that there are significant differences in the treatment of large bayat in Entisols with other treatments, except for the large Kasongan treatment in Entisols. Kasongan pottery volume of 3 liters has a better level of efficiency compared to others. Water seepage from pottery walls is influenced by the saturated hydraulic conductivity of the pottery material, wall thickness, surface area, soil type, plant type, and evapotranspiration rate [9]. The size and diameter of the pots have a significant effect on the rate of water loss. It is related to hydrostatic pressure. The greater the size and diameter of the pot, the greater the hydrostatic pressure. In this study, small pottery experienced less water loss than large pottery treatment. In addition, the type of soil also affects the rate of water infiltration through the suction matrix of the soil. In this study, Entisols experienced a higher water loss than Alfisols. The permeability of entisols is higher than alfisols so that the soil can easily pass water [10].

Table 5. Plant height measured up to 8 weeks

| Treatment | wk 1 | wk 3 | wk 4 | wk 5 | wk 7 | wk 8 |
|-----------|------|------|------|------|------|------|
| T1 U1J1   | 8.0a | 19.7a| 26.7b| 30.8b| 38.7a| 51.7a|
| U2J1      | 14.0a| 24.0a| 31.0b| 34.7ab| 38.3a| 42.0a|
| U1J2      | 14.0a| 25.0a| 32.0ab| 35.5ab| 42.0a| 47.8a|
| U2J2      | 25.3a| 36.3a| 43.3ab| 44.0ab| 51.7a| 56.3a|
| T2 U1J1   | 24.3a| 35.3a| 42.3ab| 42.7ab| 44.0a| 51.3a|
| U2J1      | 24.3a| 35.3a| 42.3ab| 45.0ab| 49.7a| 52.2a|
| U1J2      | 18.0a| 29.0a| 36.0ab| 37.3ab| 40.0a| 42.2a|
| U2J2      | 26.3a| 37.3a| 50.5a| 52.0a| 54.0a| 57.5a|

Mean in column followed by same letter is not significantly different based on Tukey 0.05.

T1: Alfisols; T2: Entisols; U1: Pottery vol. 7lt; U2: Pottery vol. 3,7lt; J1: Bayat Pottery; PP2: Kasongan Pottery

Plant height 1-6 weeks on Entisols produced the highest value compared to Alfisols. In addition, the pottery treatment volume of 3.7 liters produced the highest value in weeks 1-7, except for the second and third weeks there was no significant difference. Up to 8 weeks plant height was not significant for all treatments. This shows that 3 liters pottery with a more efficient amount of irrigation does not cause problems in plant height.
Table 6. Eggplant fruit weight for 2 times harvesting

| Treatment | Yield 1 (gr) | Yield 2 (gr) | Total     |
|-----------|--------------|--------------|-----------|
| T1        |              |              |           |
| U1J1      | 0.0c         | 108.0ab      | 108.0c    |
| U2J1      | 39.0c        | 49.7b        | 88.7c     |
| U1J2      | 0.0c         | 203.7ab      | 203.7c    |
| U2J2      | 55.7c        | 311.3a       | 367.0a    |
| T2        |              |              |           |
| U1J1      | 133.3b       | 178.3ab      | 311.7bc   |
| U2J1      | 165.0ab      | 109.3ab      | 274.3bc   |
| U1J2      | 25.7c        | 98.3ab       | 124.0c    |
| U2J2      | 183.7a       | 141.0ab      | 324.7b    |

Mean in column followed by same letter is not significantly different based on Tukey 0.05.

T1: Alfisol; T2: Entisol; U1J1: Bayat Besar (7 liters); U2J1: Bayat small (3 liters); U1J2: Kasongan Besar (7 liters); U2J2: Kasongan small (3 liters)

In alpha soil, the first harvest of large pottery did not produce fruit, and it was not until the second harvest that eggplant fruit was produced. In the Table 6, it can be seen that Entisol soil gives eggplant yield faster than alpha soil. The treatment that produced the most fruit was the Kasongan small treatment at Alfisol. Kasongan small pottery also gave the best fruit yields on Entisol soils. A good planting medium is a medium that is able to provide sufficient amounts of water and nutrients for plant growth. Basically, providing water for eggplant plants that is effective with the maximum plant production is by providing water with 80% of the water needs of eggplant plants. Based on the calculation of Etc values, eggplant needs 135.14 liters during its growth phase. If the best water supply is 80% of the plant water requirement, the water supply for eggplant plants is 108.11 liters. Meanwhile, Kasongan small treatment at Alfisol resulted in a total seepage of 101.16 liters. Not much different from giving effective water to eggplant plants.

Table 7. Tukey test results on the treatment of soil physical properties

| Treatment | Soil Moisture Agt (%) | Soil Moisture Sept (%) | Soil Moisture Oct (%) | Particle Density (mg cm⁻³) | Bulk Density (gr cm⁻³) | Porosity (%) |
|-----------|-----------------------|------------------------|-----------------------|---------------------------|------------------------|-------------|
| T1        |                       |                        |                       |                           |                        |             |
| U1J1      | 22.66ab               | 19.42ab                | 17.19bc               | 1.42b                     | 0.86b                  | 39.89a      |
| U2J1      | 19.60b                | 15.14b                 | 13.94c                | 1.61ab                    | 1.01ab                 | 37.08a      |
| U1J2      | 20.99ab               | 16.36b                 | 21.75ab               | 1.85ab                    | 1.09ab                 | 41.39a      |
| U2J2      | 20.47ab               | 17.87ab                | 15.37c                | 1.67ab                    | 1.01ab                 | 39.24a      |
| T2        |                       |                        |                       |                           |                        |             |
| U1J1      | 26.36ab               | 22.29a                 | 117.34bc              | 2.15a                     | 1.42a                  | 33.93a      |
| U2J1      | 27.80a                | 17.57ab                | 14.17c                | 1.83ab                    | 1.22ab                 | 32.97a      |
| U1J2      | 19.90b                | 19.44ab                | 22.47a                | 1.83ab                    | 1.10ab                 | 38.93a      |
| U2J2      | 24.86ab               | 20.38ab                | 18.56abc              | 1.84ab                    | 0.98b                  | 46.55a      |

Mean in column followed by same letter is not significantly different based on Tukey 0.05.

T1: Alfisol; T2: Entisol; U1J1: Bayat Besar (7 liters); U2J1: Bayat small (3 liters); U1J2: Kasongan Besar (7 liters); U2J2: Kasongan small (3 liters); K: Humidity; BJ: Specific Gravity; BV: Volume Weight

Soil moisture is very influential in cultivating eggplant. Moisture observations were carried out every day for three months. There is a significant difference in the treatment at Alfisols and Entisols. Based on this Table 7, it is known that the highest humidity from the three months occurred in the Entisols treatment. Particle density and bulk density parameters also had the highest values in the Entisols treatment. The high BV value in Entisols occurs due to a connection with the soil fraction which is dominated by sand fraction. The results of the above analysis show that the high humidity in Entisols is directly proportional to the analysis on the amount of water seepage. It is known that the highest amount of water seepage also occurred in the Entisols treatment, so it can be concluded that the...
provision of water can affect the moisture value of the soil. Factors that affect soil moisture are rainfall, soil type and evapotranspiration rate [15].

Table 8. Soil chemical properties parameters after harvesting.

| Treatment | pH H₂O | pH KCl | C-Organik |
|-----------|--------|--------|-----------|
| T1 U1J1   | 6.27ab | 4.81ab | 2.40a     |
| U2J1      | 6.39a  | 5.39a  | 2.29a     |
| U1J2      | 6.41a  | 5.22ab | 2.17a     |
| U2J2      | 6.43a  | 5.16ab | 2.75a     |
| T2 U1J1   | 5.57c  | 3.97b  | 1.82a     |
| U2J1      | 6.12abc| 4.84ab | 1.58a     |
| U1J2      | 5.73bc | 4.49ab | 1.74a     |
| U2J2      | 6.26ab | 5.02ab | 1.31a     |

Mean in column followed by same letter is not significantly different base on Tukey 0.05.

T1: Alfisols; T2: Entisols; U1J1: Bayat Besar (7 liters); U2J1: Bayat small (3 liters); U1J2: Kasongan Besar (7 liters); U2J2: Kasongan small (3 liters)

From Table 8, it can be seen that the pH of Alfisols is relatively higher than the pH of the Entisol soil. However, the c-organic parameter was not found any significant difference from the treatment used. The value of soil temperature, soil moisture has an effect on the high and low pH values of the soil at various ages of plantation crops [16]. The groundwater content of seepage from pottery affects soil temperature and ultimately affects the soil pH value. pH measurements reflect the chemical reactions of water and nutrient solutions [17]. Generally, Alfisols has a low c-organic content, which is <2%. The soil used for research has been given organic matter during soil processing. Nariratih et al (2013) explained that the value of carbon content in soil is influenced by the activity of microorganisms in remodelling soil organic matter, evapotranspiration or transport during harvest [18].

4. Conclusion

Reducing water application irrigation and improved crop water use efficiency are very important to response the climate change. In subsurface irrigation the pottery size and pottery origin affect irrigation efficiency and eggplant yield. The greater the volume in the pottery resulting in higher the hydrostatic pressure thus loss water more than of small size pottery. The big size pottery of Bayat in Entisols consume water irrigation larger than other treatment. Kasongan pottery volume of 3 liters has a better level of efficiency compared to others. Up to 8 weeks plant height was not significant for all treatments, thus the 3 liter pottery with a more efficient amount of irrigation does not cause problems in plant height. The highest soil moisture from the three months occurred in the Entisols treatment. Entisol soil gives eggplant yield faster than alpha soil. Entisol has higher soil moisture content during three months then of alfisol. Entisol soil gives eggplant yield faster than alpha soil. The treatment that produced the most eggplant fruit was the Kasongan small size pottery at Alfisols, and same trend in Entisol soils. Analysis of the Bayat pottery material has a silty clay texture with a low COLE value, and Kasongan material has a clay texture with a high COLE value.

References
[1] Las I, Pramudia A, Runutunuwu E, Setyanto P 2011 Anticipation of climate change in security national rice production J Agric Innov Dev 4(1) 76-86
[2] Shahid S 2011 Impact of climate change on irrigation water demand of dry season Boro rice in northwest Bangladesh Climate Change 105(3) 433-53
[3] Jafar I M, Tamrin M M and Zulfiana I S 2018 Pemanfaatan sistem irigasi tetes (SIT) organik pada tanaman cabai rawit (Capsicum Frutescens L.) di Kelurahan Dembe I, Kecamatan Dembe, Provinsi Gorontalo Proceeding SNKPPM 1(1) 201-5
[4] Sirait S, Saptomo S K, Purwanto M Y J 2015 Rancang bangun sistem otomatisasi irigasi pipa
lahan sawah berbasis tenaga surya *Jurnal Irrigasi* 10(1) 21-32
[5] Ariandi L M, Putra G M D, Abdullah S H 2018 Analisis komposisi serbuk gergaji terhadap konduktivitas hidrolik pipa mortari irigasi tetes bawah permukaan tanah *Jurnal Ilmiah Rekayasa Pertanian dan Biosistem* 6(1) 39-52
[6] Rosin K G, Kaur R, Patel N, Rajput T B S and Kumar S 2017 Yield and Irrigation Water Use Efficiency of Bottle Gourd (Lagenaria sicenaria L.) In Response to Different Irrigation Methods and Planting Geometries *Int. J. Curr. Microbiol. App. Sci.* 6(5) 2475-81
[7] Bhayo W A, Siyal A A, Soomro S A and Mashori A S 2018 Water saving and crop yield under pitcher and wick irrigation methods *Pak. J. Agri. Agril. Engg. Vet. Sci.* 34(1) 57-67
[8] Winarno T 2016 Penentuan jenis mineral lempung hasil pelapukan batuan metamorf di Perbukitan Jiwo, Bayat dan arahan penggunaannya sebagai bahan galian industri *Proceeding, seminar nasional kebumian ke-9 peran penelitian ilmu kebumian dalam pemberdayaan masyarakat* (Yogyakarta: UGM) pp 401-9
[9] Siyal A A, Siyal A G, Siyal P, Solangi M and Khatri I 2016 Pitcher irrigation: effect of pitcher wall properties on the size of soil wetting front *Sci. Int. (Lahore)* 28(2) 1299-1304
[10] Surono J, Husain Y E B, Kamagi, Lengkong J 2013 Geographical information system application in predicting erosion using the USLE method in the Dumoga Sub-watershed COCOS Available: https://ejournal.unsrat.ac.id/index.php/cocos/article/viewFile/2372/1906.
[11] Mariana M 2017 Pengaruh media tanam terhadap pertumbuhan stek batang nilam (Pogostemon cablin Benth) *Agrica Ekstensia* 11(1) 1-8
[12] Rezky FL 2018 Pengaruh jumlah pemberian air dengan sistem irigasi tetes terhadap pertumbuhan dan hasil tanaman terung ungu (Solanum melongena L.) *Jurnal Agrohita* 2(2) 10-9
[13] Nadzif H, Andrasto T, Aprilian S 2019 Sistem monitoring kelembaban tanah dan kendali pompa air menggunakan arduino dan internet *Jurnal Teknik Elektro* 11(1) 26-30
[14] Rahmat S, Khairullah, Sufardi 2020 Sifat residu pembenah Darussalam setelah pembenah tanah pada pertanaman sawi musim tanam ke empat *Jurnal Ilmiah Mahasiswa Pertanian* 5(2) 317-26
[15] Karyati, Putri R O and Syafrudin M 2018 Suhu dan kelembaban tanah pada lahan revegetasi pasca tambang di PT Adimitra Baratama Nusantara, Provinsi Kalimantan Timur *AGRIFOR: Jurnal Ilmu Pertanian dan Kehutanan* 17(1) 103-114
[16] Karamina H, Fikrinda W and Murti A T 2017 Kompleksitas pengaruh temperatur dan kelembaban tanah terhadap nilai pH tanah di perkebunan jambu biji varietas kristal (Psidium guajava l.) Bumiji, Kota Batu *Jurnal Kultivasi* 16(3) 430-43
[17] Astuti A D 2014 Kualitas air irigasi ditinjau dari parameter DHL, TDS, pH pada lahan sawah desa Bulumans Kidul Kecamatan Margoyoso *Jurnal Litbang* 10(1) 35-42
[18] Nariratih I, Damanik B, Majid M, Sitanggang G, Sitanggang G 2013 Ketersediaan nitrogen pada tiga jenis tanah akibat pemberian tiga bahan organik dan serapannya pada tanaman jagung *Jurnal Online Agroekoteknologi Universitas Sumatera Utara* 1(3) 479-88

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