**International Journal of Civil Engineering and Technology (IJCIET)**
Volume 9, Issue 1, January 2018, pp. 797–806, Article ID: IJCIET_09_01_077
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=1
ISSN Print: 0976-6308 and ISSN Online: 0976-6316



# RING-TYPED EMITTER SUBSURFACE IRRIGATION PERFORMANCES IN DRYLAND FARMINGS

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## ABSTRACT

*Irrigation system using ring-type emitter is one of the subsurface irrigation system forms which is done by placing an emitter around the root zone. With the addition of mulch applications, water losses from evaporation in this irrigation system can be reduced. This kind of irrigation system is suitable for dryland. The purpose of this research is to develop an irrigation system with ring-type emitter on annual and perennial crops in dryland. Perennial crops consist of young Vine-crops, young Mango crop, and Srikaya crop, while annual crop used was the Bird Pepper crop. In the application of this system to annual crops, two Mariotte tubes were used to supply 106 Bird Pepper crops. Solar energy was used as a pump energy source to fill the Mariotte tubes and the energy for the microcontroller data logger. Meanwhile, for the perennial crops, one Mariotte tube was used for one crop. The soil texture at the study site was Sandy-Clay-Loam, which was dominated by 59.67% of sand. Rainfall during* *the study was 58.5 mm. Drylands that used to be fallow during the dry season, can now be used for agricultural activities with the application of the ring irrigation system.*

**Keywords:** Dryland farming, ring-typed emitter, solar energy, subsurface irrigation.

**Cite this Article:** Joko Sumarsono, Budi Indra Setiawan, I Dewa Made Subrata, Roh Santoso Budi Waspodo and Satyanto Krido Saptomo, Ring-typed Emitter Subsurface Irrigation Performances in Dryland Farmings, International Journal of Civil Engineering and Technology, 9(1), 2018, pp. 797–806.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=9&IType=1

## 1. INTRODUCTION

The terminology of dryland has some meaning in the international world hence some of the following words are often mentioned: dryland, upland, and unirrigated land. According to the World Atlas of Desertification, dryland is a climate zone with a P / ETp ratio between 0.05 - 0.65 in the arid, semi-arid and dry sub-humid areas [1].

In general, East Lombok (Lombok Timur) Regency is a dry area. The climate condition is classified as dry with average annual rainfall ranging from 500-1000 mm (Pringgabaya, Labuhan Haji/Selong, Pegondang, Sepapan, and Sambelia). According to the Oldeman climate type classification, the central and western areas which have height > 700 m above sea level are classified as D3 agroclimatic zones with 4 wet months and 6 dry months. Areas in the eastern part with an altitude of 300-700 m above sea level are classified as D4 agroclimatic zone with 3 wet months and 7 dry months. While areas with altitude <300 m above sea level along the north-east-south coast have the E4 agroclimatic zone that has no wet month and dry month for 8 months. The location of the research is in the E4 agroclimatic zone [2].

Subsurface drip irrigation systems are often recommended to overcome water scarcity in arid and semi-arid regions [3]. Subsurface porous clay pipe irrigation is widely considered to be a very promising method for small scale irrigation in arid regions. [4]. Although saving water, subsurface drip irrigation requires a relatively high initial investment [5] and this irrigation also requires a relatively high quality of water cleanliness. Irrigation water that has ~~a~~ salt content can clog the emitter pores [4, 6].

Solar-powered drip irrigation has been tried as a strategy of enhancing food security in the rural Sudano–Sahel region of West Africa. The Research on the first year harvest in those villages, presented that solar-powered drip irrigation significantly increased both household incomes and nutritional intake, particularly during the dry season, and was cost-effective compared to other alternative technologies [7]. Pump irrigation with solar energy sources has been able to overcome the severe detriment of grasslands in China as a combined effect of global climate change and increased human activity. The solar panels that generate electricity are used to drive the pump with wells or reservoirs as the water sources [8]. A solar-powered water pumping unit integrated with drip irrigation was designed, installed and tested in a solar farm in Jalgaon, Maharashtra, India [9]. Solar-powered water pumping is not only suitable for urban, rural and community water supplies, but it is also suitable for the remote locations with no access to electricity [10]. A solar-powered drip irrigation for cauliflower plant with a discharge of 1.6 liters per hour, has better efficiency than larger discharges. To irrigate a 1000 $m^2$ cauliflower plot, a 4.4 $m^2$ solar panel width is required [11]. Beside solar energy, wind energy is also used as a source of pump irrigation in Iraq [12] and irrigation control energy sources in India [13].

The irrigation system with ring-type emitter is a developed subsurface drip irrigation, that has advantages identical to the subsurface irrigation systems, with the irrigation water that accumulates in the root zones as the specific advantage. This irrigation system requires a relatively small pressure head, so the water pump is only used when filling the water into Mariotte tube.

The objective of this study is to observe the performance of the ring irrigation system on dryland applied to annual and perennial crops. Solar energy is used as the energy source for data loggers and water pumps. It is expected that with the implementation of this system, agricultural activities during the dry season can still be operated in dry areas at the research sites.

## 2. MATERIAL AND METHODS

### 2.1. Location

The research was conducted in Pringgabaya Utara Village, Pringgabaya Sub-District, East Lombok Regency, West Nusa Tenggara Province. For annual crop experiments located at 8°31'58.32"S, 116°37'44.85"E; and the perennial crops at 8°31'18.40"S, 116°37'46.40"E (Figure 1).

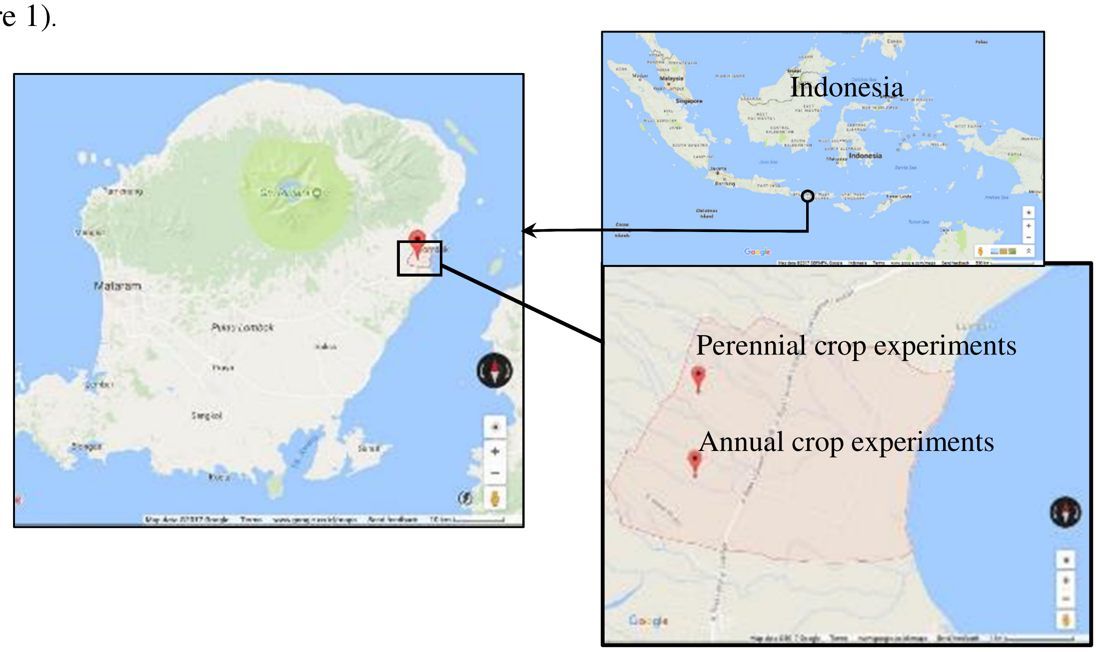


**Figure 1** Research location in Pringgabaya Utara Village, Pringgabaya, Lombok Timur

### 2.2. Equipments and Materials

The equipments used in this study are classified into two parts, namely hardware and software. Hardware used include Arduino Uno, solenoid valve, solar panel, charge regulator, power inverter, battery, water pump, SD memory shield, soil moisture sensor i.e. Vegetronix VH400 sensor, and computer while the software used is Arduino IDE v.1.5.4.

The annual crop used is Bird Pepper (Capsicum frutescens L.). The perennial crop consists of young Vine crops (Vitis vinifera L.), young mango crops (Mangifera indica L.), and Srikaya crops (Annona squamosa L.). The fertilizer used in this research is manure.

## 2.3. Ring Emitter

The ring emitter is made of a flexible plastic cylindrical hoses coated with a porous textile material with 20 cm diameter. According to Reskiana et al [14], textile materials which can be used for a ring emitter are made of Legacy textile with 1,54 cm /hour conductivity, and Colossal textile with 0,76 cm/hour conductivity. Since the Colossal type material is not available in the market, the Legacy material is chosen for the porous material. According to the results of the test, a ring emitter with a diameter of 20 cm with a legacy porous material can produce an average discharge of 0.31 l/hour. The ring emitter design can be seen in Figure 2.

The emitter consists of waterproof wall, porous wall, and emitter hole. For the Bird Pepper crop, the size of circular diameter (d1) is 20 cm with emitter diameter (d2) 5/8", for the Vine and Mango crops with d1= 40 cm with d2 = 3/4", and the Srikaya crop d1 = 2 m with d2 = 1".

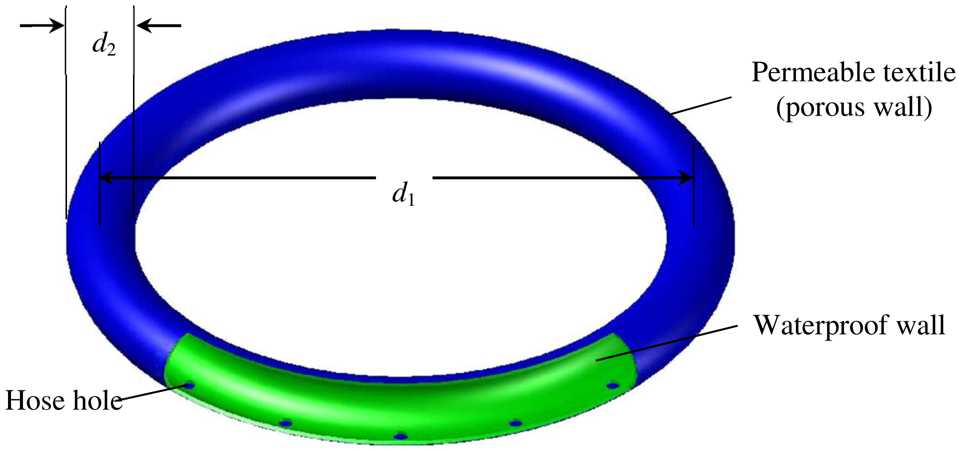


**Figure 2** Design of the emitter ring

## 2.4. Data Collection

In the ring irrigation system for the Bird Pepper, a 52.75 m2 experimental plot was divided into 2 plots (top and bottom) with size 5 m × 4.5 m and 5.5 m × 5.5 m. Upper plot was planted with 40 Bird Pepper crops and the bottom plot with 66 crops. Two Mariotte tubes were required for the two fields. The cultivation of Bird Pepper seedlings was on June 24, 2014. To reduce groundwater loss due to evapotranspiration, mulch with rice straw was applied. This mulching application could also reduce the growth of weeds.

The ring irrigation network was applied at the root area of the Bird Pepper crops with a depth of 5 - 10 cm from the soil surface. The cultivation space that was 50 cm × 100 cm. The layout of the ring irrigation system of the Bird Pepper crops can be seen in Figure 3. The real picture in the field of the ring irrigation system of perennial crop is shown in Figure 4.

The ring irrigation system was applied independently to each of the perennial crops, meaning 1 crop had 1 independent ring irrigation system. In the Vine crop ring irrigation system, there were 4 crops with 4 ring emitters and 4 Mariotte tubes. In the Mango crop, there was only 1 crop with 1 ring irrigation system, and there was also only 1 crop with 1 ring irrigation system in the Srikaya crop.

The emitter depth in all perennial crops was 20 cm below ground level. Rice husk mulch was applied at the soil surface, and for the young crops, an invidual fence for each crop was constructed. The Mariotte tube was made of an iron drum that has a modified discharge hole, with low pressure irrigation water flows (5 cm water).

## 2.5. Soil Samples and Weather Data

The soil samples (undisturbed soil sample) were taken from the research site using ring samplers. Based on the soil analysis from the laboratory, several parameters were obtained and further used for groundwater retention analysis. These parameters were the total pore spaces and soil moisture contents (pF1, pF2, pF2.5, pF4.2). The equation used was the Van Genuchten Equation [15]. Potential evapotranspiration ($ET_0$) was calculated using the Hargreaves Method [16-18].

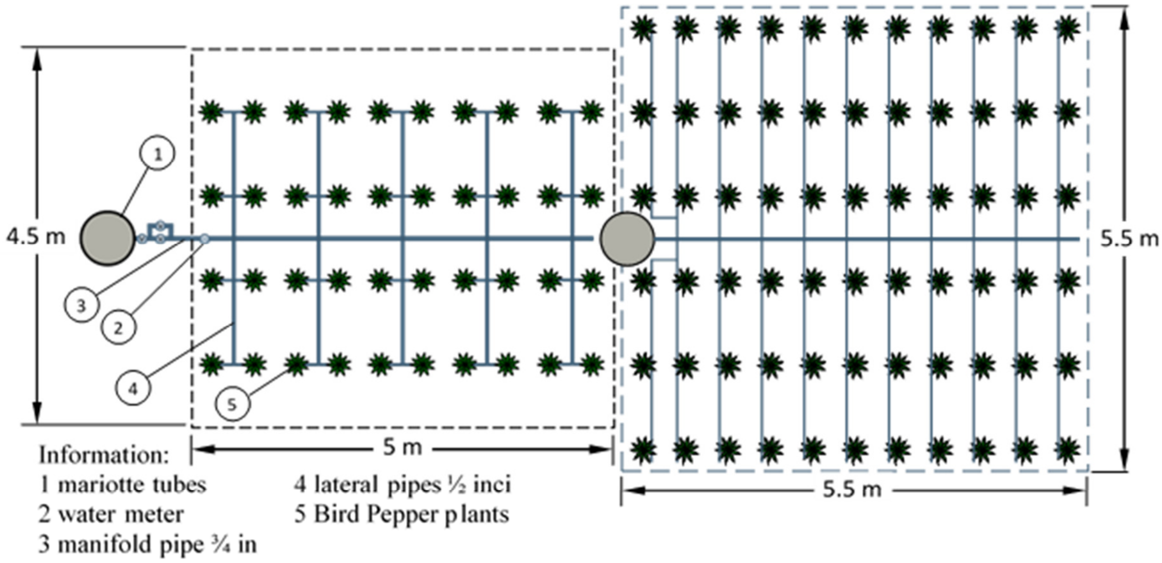


**Figure 3** Ring irrigation system layout on a Bird Pepper crops


**Figure 4** Ring irrigation system on (a) perennial crop, (b) Mango crop, (c) Srikaya crop

# 3. RESULTS AND DISCUSSION

## 3.1. Dry land Conditions at the Study Sites

The location of the research was dryland where mostly ws rainfed agriculture land. The corn crops dominated the agricultural activity which is only one planting season per year. A small part of the land was an area irrigated by using three deep groundwater pumps. Almost all irrigation network infrastructures (irrigation pipes) began out of order, resulting that the irrigation water was distributed through surface flow. This condition caused high water loss during a relatively large irrigation flow. This was due to the soil texture property (sandy-clay-loam) with the soil solum thickness less than 30 cm, and occurred during the dry climate.

The pumped water is stored in water tank placed at the upper plot. Farmers pay irrigation water based on the amount of demand, at a price of IDR. 740 per cubic meter of water or USD 0.06 (exchange rate Sep - Nov 2012, USD 1 = IDR 12, 100).

This irrigated area can be planted at all times, where selected high economic valued crops such as Srikaya and Bird Pepper are planted. The obstacle farmers faced is the frequent broken down of the diesel-powered water pumps that makes farmers fail to harvest.

From January to November 2014, there was rainfall of 521.5 mm with 37 rainy days. The rainfall data from January to November 2014 is presented in Table 1. Rainfall data is obtained from rain scrapers (ombrometer) installed in the Water Management Service Office of Pringgabaya District that is located in the Pringgabaya Utara Village.

**Table 1** Rainfall Data of Pringgabaya Utara Village (mm)

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall | 109 | 160 | 110 | 84 | 0 | 1.5 | 39 | 4 | 0 | 0 | 14 |
| Rainfall day | 7 | 9 | 8 | 6 | 1 | 1 | 3 | 1 | 0 | 0 | 1 |

## 3.2. Analysis of the Soil Physical Properties

The texture of the soil samples found to be sandy clay loam. Based on the results of the analysis on the physical properties of soil, pF values and soil moisture contents were simulated with the Van Genuchten Equation, and obtained groundwater retention curve, as seen in Figure 5.

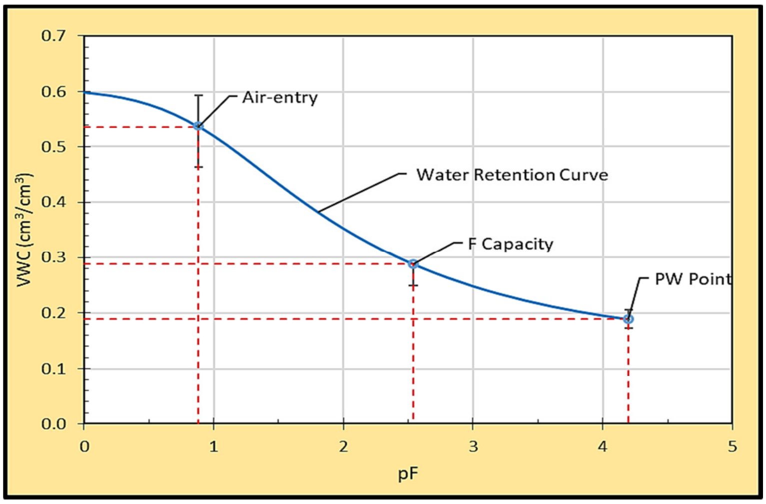


**Figure 5** Water Retention Curve

The field capacity was at a 29 cm3cm-3 soil moisture value, and the permanent wilting point was at 19 cm3cm-3. With a relatively small range, soil capacity in storing available water for crops was also relatively small. So, it is expected that this irrigation can overcome the small capacity of water storage.

### 3.3. Perennial Crop Water Consumption

The use of the Mariotte tube to supply irrigation water to the ring emitter, allows the water to flow at a constant pressure. The decrease of water in the Mariotte tube for each perennial crop is presented in Table 2.

**Table 2** Average water level drop in Mariotte tube for perennial crops

| Perenial crops | Decreased water level/day | Water volume (l/day) |
|---|---|---|
| Vine | 23 mm | 5.9 |
| Mango | 22.3 cm | 56.9 |
| Srikaya | 23.6 cm | 60.2 |

Based on the Mariotte tube capacity which is approximately 210 liters, the ideal water filling was 4 days for the Srikaya and Mango crops, as for the grapes, it could be filled once a month. It was difficult to get irrigation water in the research location, because the deep groundwater pump was often out of order, so that the fastest water filling on the crops on the average is once a week.

Based on the observations, the Vine and Mango crops showed normal live with the growth of new shoots. As for the Srikaya crop, when unirrigated crop did not grow leaves at all, it turned out that the irrigated Srikaya crop could grow leaves, but did not flower and produce fruit.

### 3.4. Water Consumption of Annual Crops

To find out the continuity of the rooting conditions of Bird Pepper crops, a soil moisture sensors was placed in the root zone. Data logger used was the Arduino Uno microcontroller. Soil moisture conditions can be seen in Figure 6.

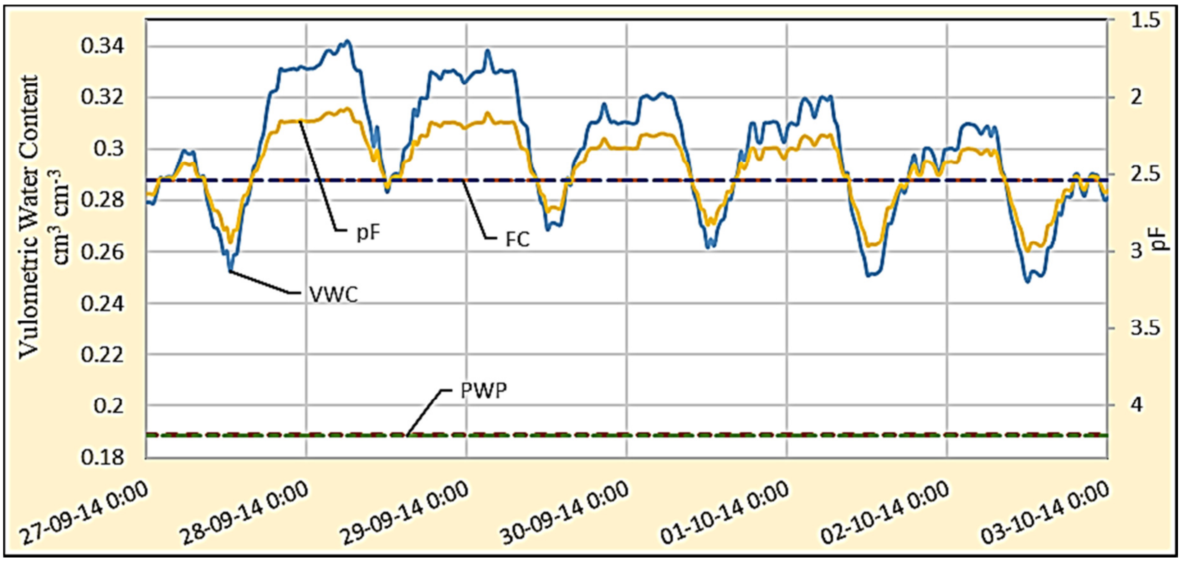


**Figure 6** Conditions of Soil Moisture in the Root Zone of Bird Pepper Crops

Figure 6 shows that the soil moisture conditions were always maintained by the ring emitter in a range not far from the field capacity value (pF 2.54). Soil moisture fluctuated; decreased during the day and increased during the night.

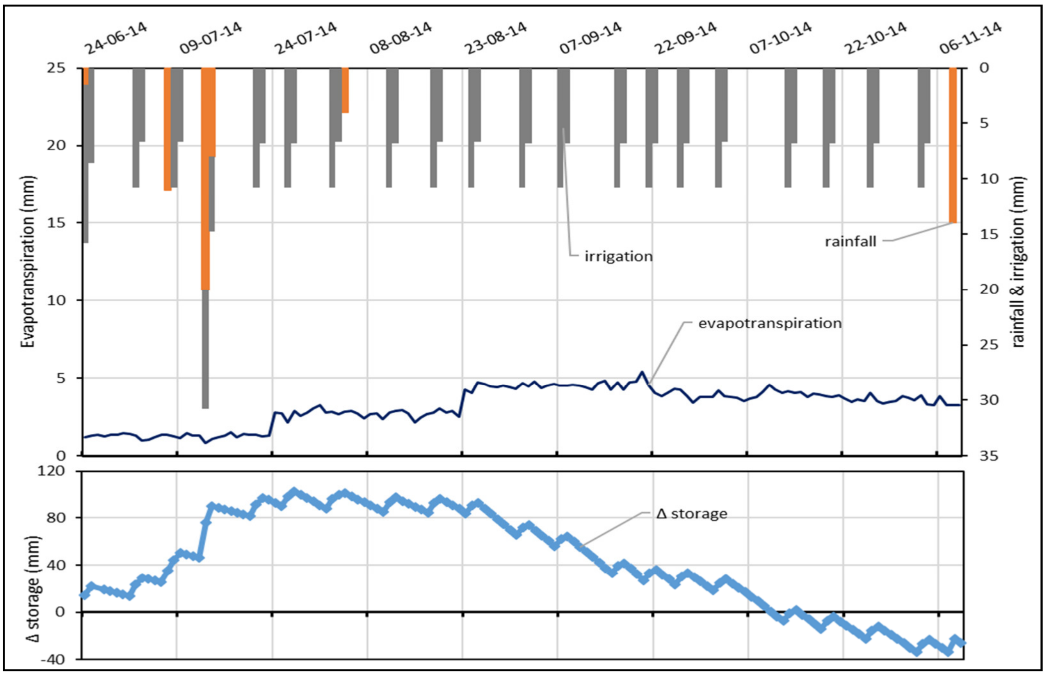


**Figure 7** Water Balance Graph of Ring Irrigation System on Bird Pepper Crops

The amount of rainfall during the study from June to November 9, 2014 was 58,5 mm (6 days). The total irrigation water flowed through the Marrriotte tube was 8.52 m3, and the average radius of wetting emitter ring was 0.27 m. Thus, the total given irrigation thickness was 357 mm. The water balance in this irrigation system is shown in Figure 7 and Table 3.

**Table 3** Water Balance of Ring Irrigation System of the Bird Pepper Crops

| Variable | Irrigation | Precipitation | Evapotranspiration | Change in storage |
|---|---|---|---|---|
| Depth (mm) | 353 | 58.5 | 441 | 29.5 |

The total potential evapotranspiration during the study was 629 mm. The values of the coefficient of Bird Pepper were 0.3 for the first month, 0.6 for the second month, 0.95 for the third month, 0.85 for the fourth month, and 0.8 for the fifth month and so on. Using the coefficient values of the crop, the actual total evapotranspiration was 441 mm.

Taking into account the amount of rainfall, total irrigation provided, and the total actual evapotranspiration, there was 29.5 mm water use saving. This saving (reduce the amount of evaporation) assumed caused by both the location of the emitter (below the soil surface) and the mulch applications during planting. Figure 8 shows daily soil moisture fluctuation. If an equation is made to approximate the fluctuation phenomenon, a Sine Equation may be used. With the help of an excel solver by minimizing the RMSE value or maximizing the value of R2, the equation is given in Figure 8. From the equation, one could draw the axis of the sine equation, which found to have the value of 0.01.

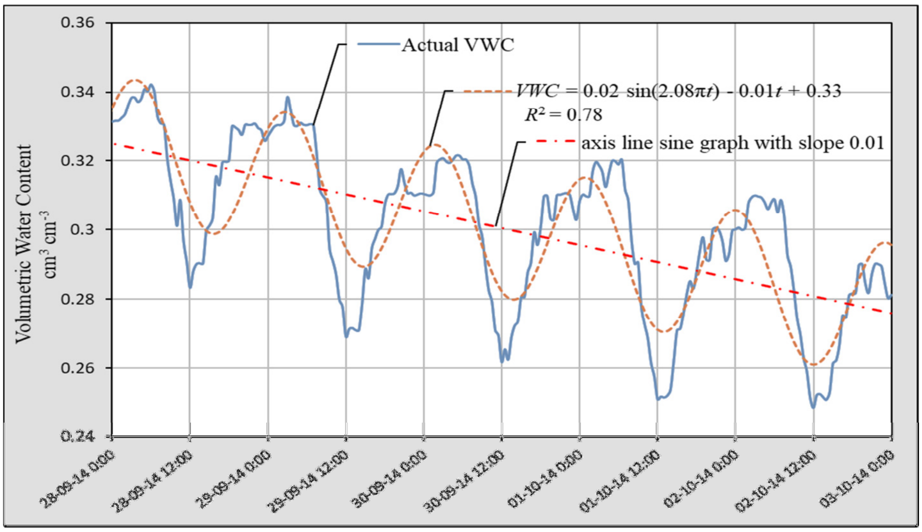


**Figure 8** Slopes of Soil Moisture Value Fluctuations in Pepper Bird crop

The axis had a slope value of - 0.01, so, it could be assumed that the soil moisture decrease was 0.01 cm3cm-3 per day. Based on the soil analysis results that the difference between the value of field capacity and the permanent wilting point was 0.1 cm3cm-3, so, if the irrigation was given up to the field capacity, then, at the latest after 9 days the crops must be irrigated again. In this study, irrigation was applied, on the average, every 7 days.

In the future, technology must play important role in improving the efficiency of irrigation and minimizing agricultural water consumption [19-21]. Irrigation scheduling based on a scientific approach should be able to be converted into a practical application, so it will be easy to be understood and can be used as a guide for practitioners in the field.

## 4. CONCLUSIONS

The conclusions of the research are as follows:

- Water saving can be obtained by applying a ring irrigation system.
- With this system, irrigation for perennial crops can be given once a month up to every 4 days.
- For annual crops, this system can always maintain soil moisture in the root zone at the level close to the field capacity.
- Agricultural activities still can be maintained by implementing this system, although the availability of water resources is limited.

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