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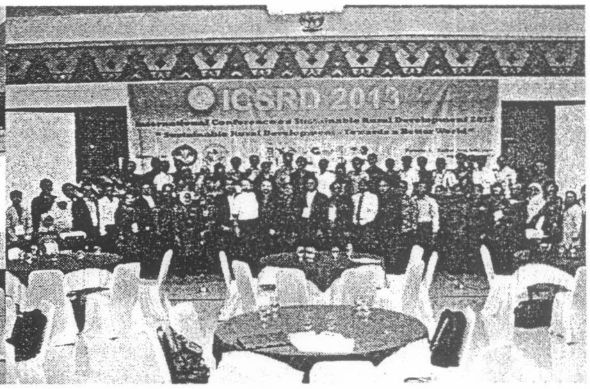

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CIRCULAR-SHAPED EMITTER AS ALTERNATIVE TO INCREASE IRRIGATION EFFICIENCY

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ABSTRACT

As respond to demand on reducing water for agricultural sector as the water usage competition is increasing between various sectors, water efficient irrigation techniques were offer in order to keep the water status at the desirable level at a production land, while avoiding loss of water and within a certain amount of water available. Automation system was applied to micro irrigation system using circular shaped irrigation emitter. The irrigation system is proven to work and keep the soil moisture at the desired condition which is field capacity, between pF 2.54 and 4.2. As the soil moisture was kept within the range percolation can be suppressed to its minimum or even halt. The system can be improved and used for dry land agriculture.

Keywords: micro-irrigation, automatic control, agriculture water management, porous medium

INTRODUCTION

At present, there is a demand for the agricultural sector can reduce water usage as the competition is increasing in water use in various sectors like power generation, domestic and industrial sectors. Uncertainties about the impacts of climate to water availability have also been a challenge to agriculture water management. One effort to adapt to this situation is by increasing water use efficiency. As respond to this situation, there are many water efficient irrigation or cultivation techniques that had been offered. The task is to keep the water status at the desirable level at a production land, while avoiding loss of water and within a certain amount of water available. At present digital electronic and information technology had been accepted widely in most aspect of living. Similarly, agricultural water management can use this modern technology. The use of electronic sensors and devices that integrated into an irrigation control system seems to have its potential to increase the efficiency of water utilization by preserving exact water status to the field. This is hopefully can contribute to improve performance of irrigation water management. Micro irrigation can increase the efficiency of irrigation water applied, although the usage of micro irrigation is limited. The method of water application is determined by the type of emitter, which can also define the efficiency. This paper aims to present the development of automated irrigation system that uses circular shaped emitter as an alternative to increase water use efficiency.

METHODOLOGY

Soil Moisture

Soil moisture regime that should be preserved for the plant is generally between field capacity (pF 2.54) and permanent wilting point (pF 4.2). Therefore, the range of soil moisture should be determined by analyzing the field's soil sample. In our case the soil samples were tested in the laboratory to get volumetric water content values at pF 1, 2, 2.54 and 4.2. Retention curve was made using van Genuchten (1980) model to estimate the soil moisture at other pF values. Table 1 shows the physical properties of the soil and Figure 1 shows its water retention curve by van Genuchten. Here the objective of the irrigation is to provide water between field capacity and permanent wilting point, which volumetric water content values are 38.5% and 28.7%.

Table 1. Soil properties

Field volumetric water content	BI (BD)	Porosity	Volumetric Water Content				Drainage		Available water
			pF1	pF 2	pF2.54	pF 4.2	Rapid	Slow	
(% vol.)	g/cc	% of volume							
40.1	1.10	53.4	47.9	38.9	33.9	24.4	14.5	5.1	9.5
39.1	1.14	50.9	49.2	44.8	39.9	27.3	6.0	4.9	12.6
34.0	1.01	58.9	54.0	44.7	39.4	25.5	14.3	5.3	13.9
35.8	0.98	54.2	48.6	46.0	40.5	28.9	8.2	5.5	11.6

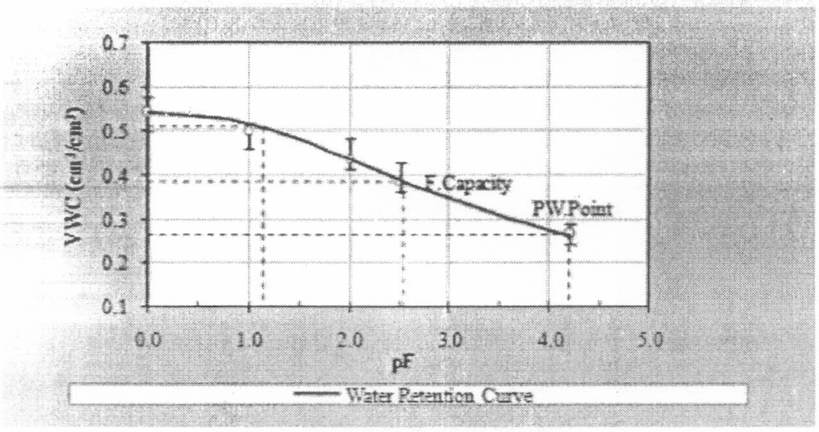

Figure 1. Water Retention Curve

Micro Irrigation and Porous Medium

According to Hansen, et al (1979), there are 4 different methods of irrigation, which are: surface, sub-surface, sprinkle and tickle irrigation. Sprinkle and tickle irrigation are examples of micro irrigation that are used limitedly. Both irrigation required manifolds and lateral pipes network that deliver irrigation water to it outlets points. As Sprinkle irrigation nozzle spread water to a wider area, tickle irrigation provides water close to the plant and applied at the surface by droplets of water.

Another innovation in irrigation is the use of porous medium as emitter. Pitcher irrigation (Setiawan, 2000) is one of the example, especially useful for arid land. Pitcher irrigation exploits the property of porous medium to control water flow from inside depends of the moisture different between porous wall of the pitcher and the soil. Similar principle can be applied to different shape of emitters.

The emitter used in this research has principles, which are to applied water as close and as uniform as possible to plant, and the water flow can be naturally limited following the property of soil. The circular shape can fulfill the first principle; this can be done by using disk-shaped porous medium or simple punching holes around the bottom of a circular container.

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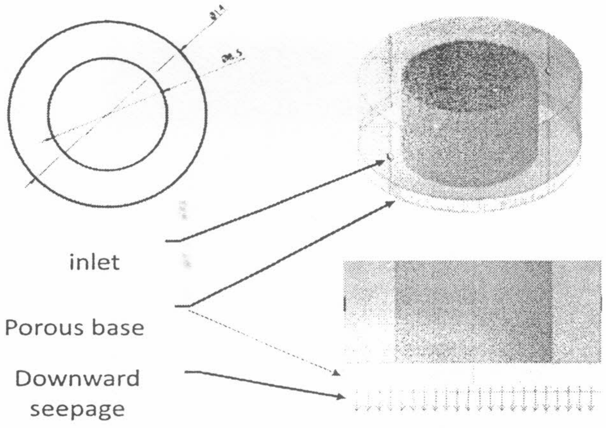

Figure 2. Circular (disc) shaped emitter

Automatic Irrigation

Automatic irrigation is part of water management system that includes irrigation and drainage. An example of this technology was developed in the research for the development of controlled drainage for wetland (Setiawan, et. al. 2002) that used automatically regulated pumps to move the water from or to the agricultural land. In this research, the automation was applied for micro irrigation. The purpose is to control the flow of water to the emitter, since in this stage the circular emitter has not been properly developed yet.

The automation system that was used in this study is a 2 setpoints on-off system based on open-source prototyping platform Arduino. Soil moisture sensors were used as the sensing device that supplied moisture status to the controller. The sensors were calibrated to the soil moisture data analyzed in the laboratory, and have linear conversion function as Eq . 1 where y_1 is the moisture value and x_1 in binary number equal to moisture sensed by the sensor.

$$y_1 = 0.1218x_1 - 20.081 \quad (1)$$

Figure 3 shows the automated irrigation system schematics. The automation system was design to be powered by solar energy.

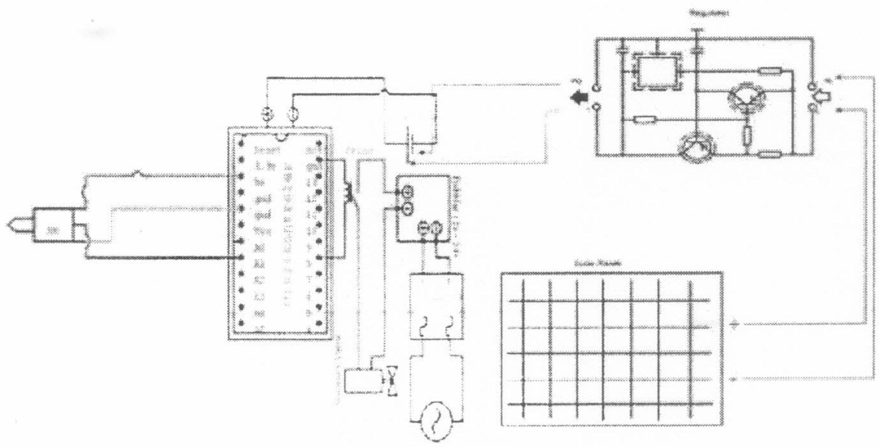

Figure 3. Solar Powered Automatic Irrigation System

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RESULTS AND DISCUSSION

Disc irrigation system has been tried for field irrigation experiment. The irrigation was controlled automatically, irrigation valve will open as soil moisture decrease to 28.7% (0.287 cm^3/cm^3) or less, and it will close as the moisture increases and reaches water content values of 38.5% (0.385 cm^3/cm^3). The layout of the irrigation system is as shown in Figure 4 The trial was done in 5 m x 2,9 m field with 30 disk shaped emitters having 14 cm of outer diameter. Each emitter can seep approximately 0.0057cm^3 of water per second or 0.0092 mm/sec, assuming the seepage is uniform beneath the emitters circle area.

A short trial was conducted in a fine day without rain, for only a few hours to examine the performance of the irrigation system. Figure 5 shows the irrigation performance during this trial, the fluctuating line is the soil moisture that was moving within the range of maximum and minimum permitted soil moisture. This was made by setting the setpoints of the controller as explain in prior section. As the moisture decreased and reach minimum setpoint, the irrigation valve opened and recharge water in the disc emitters and water seeped to the soil.

Soil moisture increases as the field was irrigated, until it reached maximum setpoint where the valve will automatically close. The remaining water in the disc emitters kept seeping even the valve had been closed; this would further increase the soil moisture higher than field capacity. In this case, small part of water percolated. Percolation happens as currently the disk shaped emitter's base's material has not been designed properly yet. The material design is the next step of the research.

Figure 6 shows the total quantity of components of water balance (mm) recorded during the trial. The input components are rainfall and irrigation which has amount of 0 mm and 7.85 mm. Output components are evapotranspiration (ET), total changes in water storage (dh/dt) and percolation (P) which have values of 1.08 mm, -2.78 mm and 9.54 mm. This water balance analysis is based on 40 mm depth of soil layer.

Percolation was higher than amount of water irrigated. The additional percolated water might be originated from the moisture storage in the soil, which changes has negative value that means moisture extracted from the soil. This could also mean that there is another source of moisture to the field whiah are not clear yet. Other possibilities are the soil layer is not 40mm as assumed or irrigation rate of the emitters was not uniform. However, the results show that the irrigation system can work well in preserving soil moisture at the favorable level and minimize loss through percolation.

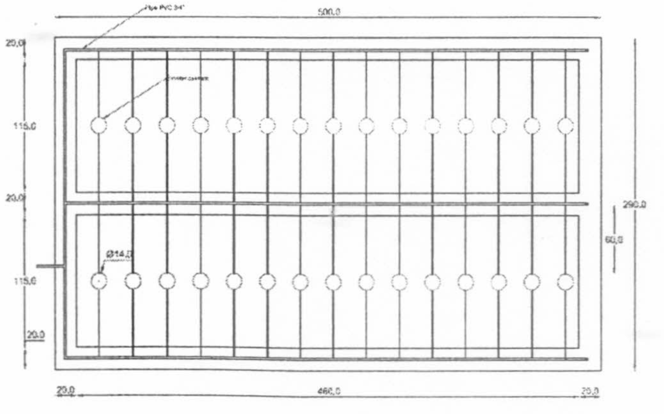

Figure 4. Disc Irrigation System Experiment Layout

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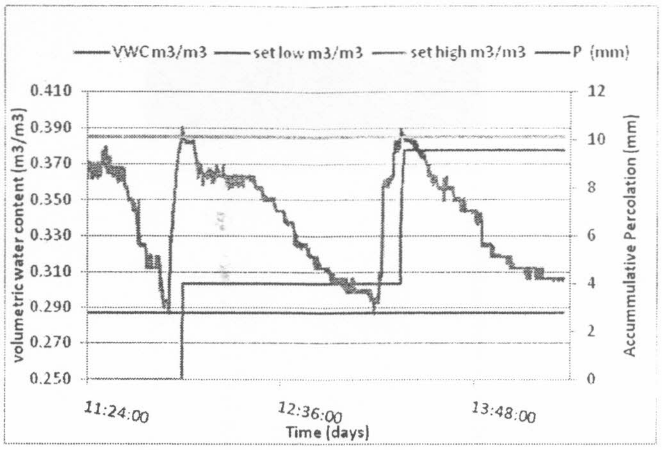

Figure 5. Irrigation performance

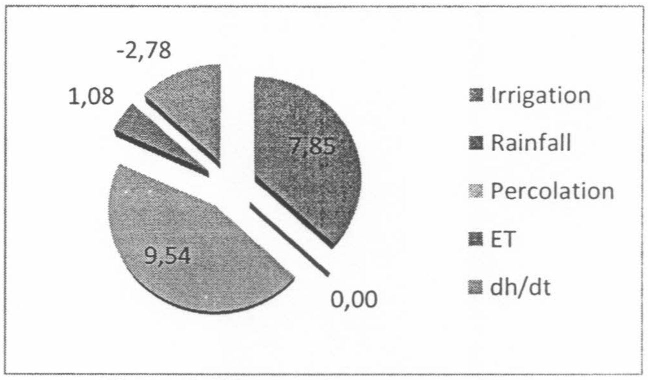

Figure 6. Water balance components

CONCLUSIONS

Disc shaped emitter was used in field trial, using automatic micro-irrigation system. Water was applied the surrounding vicinity of the plant by using the emitter. The combination of disc shaped emitter and automated irrigation system than works to preserve water between field capacity and wilting point had proven to work well. The system is still to be improved by developing better material of the emitter and the base of the emitter in the way that the circular shaped emitter can be more flexible in the installation and having better water conducting properties which can work better when implemented in dry land.

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