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Enhanced Fertigation Control System Towards Higher Water Saving Irrigation

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ABSTRACT

Water saving in agriculture is increasingly important due to critical issues of water and climatic crisis. The focus of agricultural researches nowadays is to minimize the water consumption and at the same time increasing the agricultural yield. This paper presents the three-types of automatic fertigation controller for irrigation system with different application tools. A weather station, soil moisture and timer based system were used to determine the volume of water supply needed by plants to calculate an accurate irrigation operation timing. The experiment was conducted by supplying water for capsicum annum test crop located in a greenhouse. The plant water demand parameter was calculated and compared for each application tools and the best application tool was chosen to be implemented in controlling the irrigation system.

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1. INTRODUCTION

Drip irrigation system is increasingly widespread among the individual farmers and agricultural industries. This is because the system can generate higher revenues and able to increase crop productivity significantly [1]-[3]. The drip irrigation also known as site-specific micro-irrigation system because the mixture of water and nutrients or fertigation can be supplied directly into crop root zone thus able to decrease water loss from evaporation, run off and deep percolation [4]-[6]. The amount of fertigation supplied to the crop is very important because problem will arise if not controlled efficiently. Supplying excessive resource will lead to wastage of energy and nutrient. The excessive nutrition also will pollute surrounding area and underground water. These will increase production cost and affect the environment.

The problem can be resolved by supplying the resource only when the plants need it, with an exact amount. The plant might need different amount of water during the plant growth stage since they experience different micro climate and water loss daily [3], [7]. In general, drip irrigation system is controlled using timer where the schedule is based on historical data and farmers experience. Alternatively, the irrigation controller can utilize data from soil moisture condition or reference evapotranspiration [8]-[9]. These methods might be able to determine the irrigation amount and time accurately because it is based on the plant water demand. The conventional system can be improved and the cost of farm management can be reduced when a precision irrigation system is being applied. Hence, water for irrigation can be decided by the farmer by calculating the water requirement [10], [11]. The soil moisture condition can be measured by using soil moisture sensor to measure current soil water content and determine the irrigation based on the moisture deficit [12]. For reference evapotranspiration, ETo weather station data such as temperature, humidity, net solar radiation and wind speed will be used to estimate water loss from the plant. Many farmers use water loss data as input to their irrigation control system and for water saving purpose [13]-[15].

In this study, three types of automatic drip irrigation controller are being evaluated to measure the amount of water supplied to the plant. The irrigation control method that tested in these studies are energy balance that based on weather condition, soil water balance and timer. An experiment in a greenhouse was conducted to identify the effectiveness of these irrigation control method based on the irrigation volume.

2. RESEARCH METHOD

A test crop, chilli plant was used to measure the water usage in irrigation for the three types of drip irrigation control. Cocopeat was used as the growth medium as it has a high water holding capacity. Three Bilge submersible water pumps placing at tank mixing with flow rate of 1100 gallons per hour was used to supply the mixed AB solution to the plant from each irrigation control. Figure 1 shows the layout for drip irrigation for overall system at greenhouse. Every irrigation control system line has 22 polybags installed with individual dripper which connected to the 16mm pipeline from each water pump and the Figure 2 shown the real environment inside greenhouse for experiment for the pepper. The greenhouse size are 20 feet width, 40 feet for long and 7 feet for height.

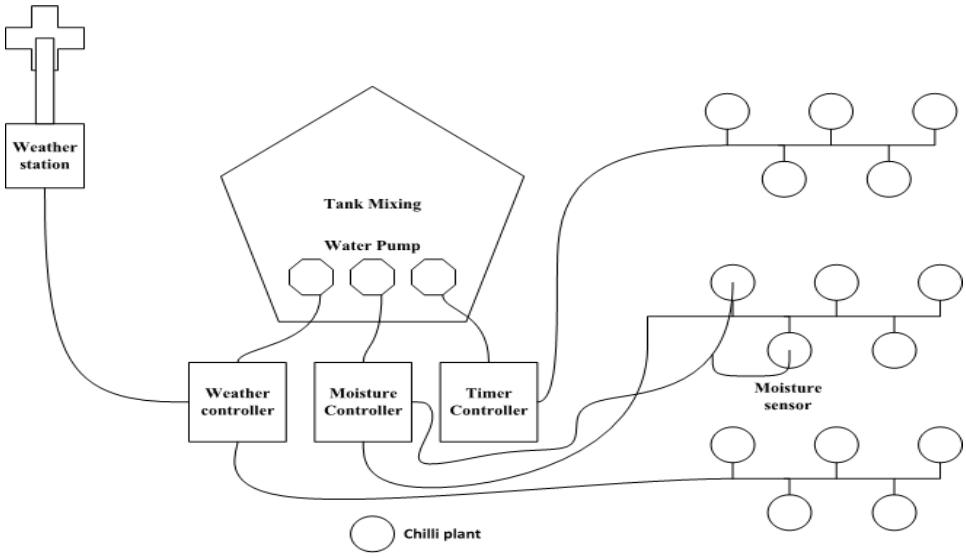

Figure 1. The system layout for drip irrigation control system

Figure 2. Chilli plant inside the greenhouse

2.1. Weather Based Irrigation Controller

The irrigation control system uses weather data (Davis Vantage Pro2 Weather Station) to estimate the amount of water loss from the plant. To replace the amount of water loss, the controller calculates the amount of water demand from the plant to be replenished. A Penman-Monteith equation (1) by Food and Agriculture Organization (FOA) was used to calculate reference evapotranspiration, ETo. In this regards, meteorological data from the weather station at the study site were used to calculate the irrigation requirement [2], [15]-[18].

$$ETo = \frac{0.408\Delta(Rn)+\gamma\left(\frac{900}{T+273}\right)U_2 e_2}{\Delta+\gamma\ (1+0.34U_{2})} \quad (1)$$

Where:

ETo = reference evapotranspiration (mm/hour)
R_n = net solar radiation (W/m^2)
γ = psychrometric (hygrometry) constant (kPa °C-1)
T = mean daily or hourly air temperature at 1.5 to 2.5-m height (°C)
U_2 = mean daily or hourly wind speed at 2-m height (m s-1)
e_s = saturation vapor pressure at 1.5 to 2.5-m height (kPa)
Δ = slope of the saturation vapor pressure-temperature curve (kPa °C-1)

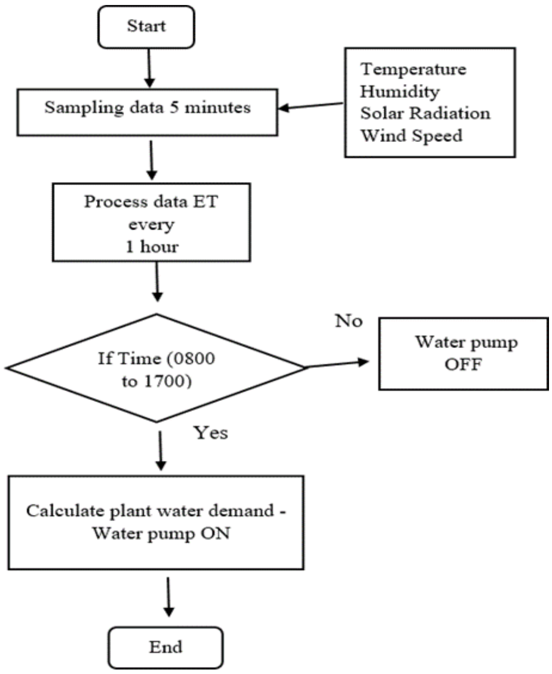

Figure 3. Weather based irrigation control operation

2.2. Soil Moisture Based Irrigation Controller

The soil moisture irrigation for this project, we can control the volume of water based on moisture content of the cocopeat medium. According to soil moisture, water pumping motor turn on or off via the relay automatically. This method able to save water, while the soil water content can be obtained in preferred aspect of the plant, thereby increasing productivity crops. Two capacitive based soil moisture sensor (VH400) were used to measure the level of volumetric water content (VWC) in the growth medium. The capacitive sensors create an output signal which is a feedback of dielectric permittivity. In this experiment, the soil moisture level has been set at 0.50 cm3/cm3 as a reference to the irrigation controller to activate water pump. This value was determined based on the field capacity of the growth medium.

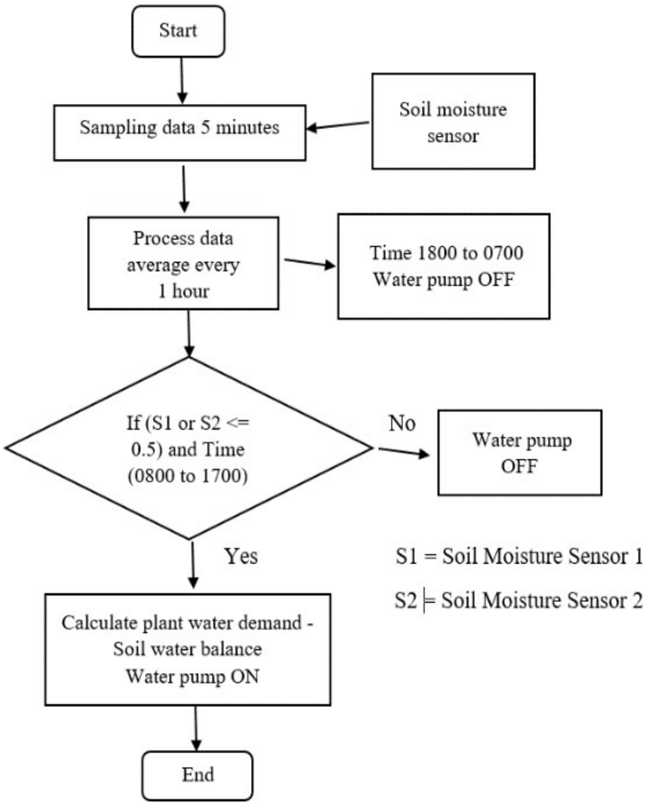

Figure 4. Soil moisture based irrigation control operation

Figure 4 shows the soil moisture irrigation controller process for pepper plant fertigation system. This experiment used two sample pepper plant to measure the volumetric water content (VWC). Soil moisture 1 and soil moisture 2 will calculated averaged hourly to determine whether water pump will be ON or OFF. The time interval irrigation will be ON for 5 minutes if the average soil moisture less than 0.5 cm3/cm3.

2.3. Timer Based Irrigation Controller

Irrigation control using timer is commonly used by farmers due to the price and simplicity on irrigation scheduling setup. Basically, the irrigation scheduling is based on historical cultivation practice and farmers' knowledge in understanding the plant water demand. In this experiment, the timer was configured to be activated five times daily from 7.00 am to 6.00 pm as shown in Table 1.

Table 1. Irrigation schedulling

Irrigation No.	Time ON	Time OFF
1	7.00 a.m.	7.05 a.m.
2	10.00 a.m.	10.05 a.m.
3	1.00 p.m.	1.05 p.m.
4	3.00 p.m.	3.05 p.m.
5	6.00 p.m.	6.05 p.m.

3. RESULTS AND ANALYSIS

The result has been collected for two days on 16/8/2017 and 17/8/2017 in an experimental greenhouse structure located at Agrotani Garden, Universiti Teknologi Malaysia, Johor Bahru, Malaysia. The plant was cultivated in the greenhouse and the result for each irrigation controller was measured from the water supplied to the respective polybags.

3.1. Weather Based Control

Figure 5 shows the amount of irrigation and desired water based on weather control system. In this system, the amount of desired water was calculated based on weather data. Based on the figure, it can be observed that the irrigation volume changed based on the volume of water desired. In this system, the amount of irrigation was supplied less than the amount of water desired by the plant. It was mainly due to the dry atmosphere and windy condition as it creates a larger driving force for water movement out from the plant and thus increase the rate of evapotranspiration.

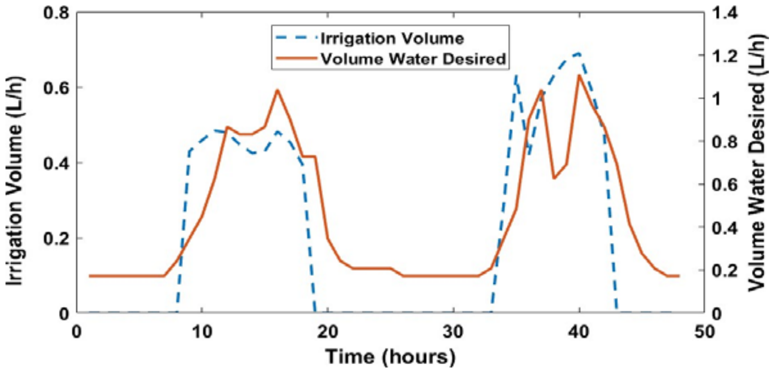

Figure 5. Reference evapotranspiration and the volume of irrigation

3.2. Soil Moisture Based Control

Figure 6 shows the soil moisture level and irrigation volume for the plants. In this control system, irrigation system will start to operate when the soil moisture level reached the value less than 0.5 cm^3/cm^3 to maintain the soil water content of 0.5 cm^3/cm^3. Based on the figure, the soil moisture based irrigation control system was able to maintain the amount of soil water content by 0.45 cm^3/cm^3 in the medium that was sampled by averaging two different plants. Therefore, this control system was able to control the amount of soil moisture level with an accuracy of 0.05 cm^3/cm^3. In addition, this controller also performing well as it operated steadily without any difficulties to provide sufficient water supply within the desired soil water content

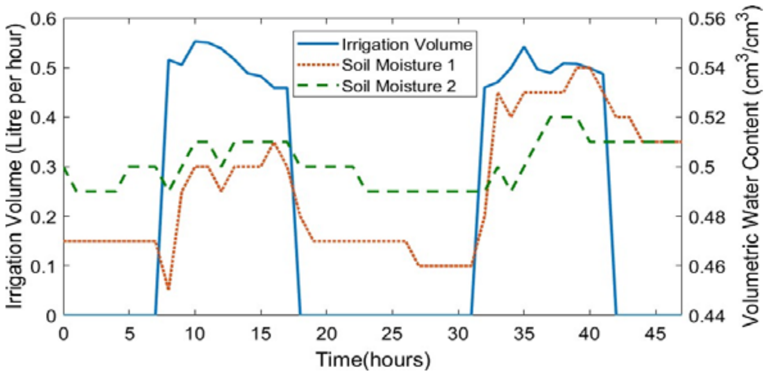

Figure 6. Soil moisture level and volume of irrigation

3.3. Timer Irrigation System

Figure 7 shows the amount of water volume used for timer irrigation system based on the timer scheduling shown in Table 1. Based on Table 1, the irrigation time for the system was set for five minutes at each interval. Therefore, it was estimated that each plant will receive the amount of water approximately around 0.5 litre at every interval. Based on Figure 7, the water volume shows some inconsistency by comparing at each interval. It was mainly due to the unstable dc pump power supply as a solar energy system was used as a main power source in this experiment.

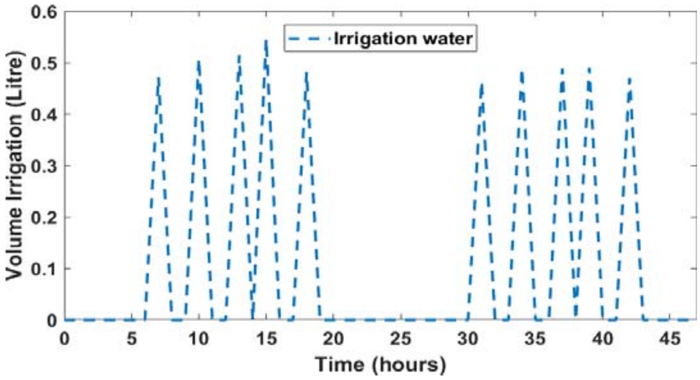

Figure 7. Timer based irrigation volume

3.4. Irrigation Water Usage

The cumulative water usage for three drip irrigation controllers was shown in Figure 8. It can be observed that the irrigation volume for moisture based and weather based controller was higher than the timer based controller with a percentage of 49 %. The final cumulative water used in a duration of two days was 108.22 litre for the timer based controller, 220.61 for the moisture based controller and 217.26 litre for weather based controller. The irrigation volume between moisture based and weather based control systems differs for about 2% which weather based control has a lower irrigation volume. Therefore, based on those comparison, a weather based control system was more preferred than the moisture based control system. Generally, to define and calculate the amount of water usage for irrigation, the amount of plant water demand need to be calculated for soil moisture and weather based control system. In the other hand, the timer based control system controls the irrigation time and volume by pre-setting the value ahead according to schedule planned by the farmer. This control system usually increases the water usage in agriculture as it supplies water based on the schedule and the amount of water demand was neglected. Therefore, at sometimes, water was supplied even though the plant does not really need the water. In this experiment, the amount of water supplied in the timer based system shows a deficit irrigation to the plant as the amount of water supplied was far lower than the system that operates based on plant water demand. Therefore, the amount of water supplied by the timer based control system was not accurate and the plant may be having a malnutrition as a result. In the other hand, the irrigation control by weather and moisture based providing a sufficient and exact irrigation amount based on the actual plant water demand. Therefore, it can be guarantee that this irrigation control system will provide an efficient soil moisture balance and energy balance for the soil-plant-atmosphere system.

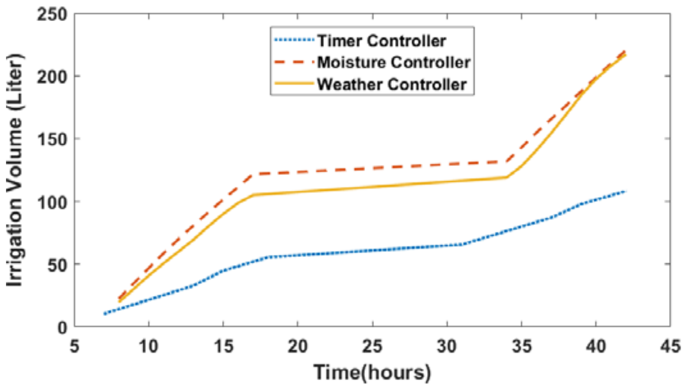

Figure 8. Cumulative total water use for irrigation

4. CONCLUSION

Provide a statement that what is expected, as stated in the "Introduction" chapter can ultimately result in "Results and Discussion" chapter, so there is compatibility. Moreover, it can also be added the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

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