SMART WATER-SAVING IRRIGATION SYSTEM BASED ON REAL-TIME WEATHER DATA IN SAUDI ARABIA.

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Abstract

An in situ field test on two types of Evapotranspiration-based irrigation controllers (ET controllers) was conducted in a sandy loam soil located at King Saud University, Riyadh- Saudi Arabia to evaluate the suitability of these technologies for agricultural applications under surface drip irrigation system compared to various time-based irrigation schedules (control treatment). The tested ET controllers were Weathermatic SL1600 and Hunter pro C controllers. Each treatment was replicated three times for a total of nine blocks. The main advantage of controlling the irrigation process by these techniques is that irrigation-scheduling program is operated automatically, based on local climate conditions derived from smart irrigation controller components (ET sensors, ET module and Irrigation controller). The results indicated that the highest water savings, averaging 28%, was obtained from Hunter pro C. Weathermatic SL1600 reflected a similar trend to water savings with similar statistical results (27%) as compared to the control. Water use efficiency and agronomical characteristics (vegetative growth, fruit quality and fruit yield traits) for ET controllers were significantly greater than the control.

Keywords: Surface Drip Irrigation, Water Use Efficiency, Smart Controllers.

INTRODUCTION

Evapotranspiration (ET) based irrigation controllers (ET controllers) are an emerging technology for adjusting irrigation applications based on actual weather and soil conditions. The concept of adjusting irrigation application to meet prevailing climate and weather conditions is as old as irrigated agriculture. The technology to control irrigation application automatically has been included in large-scale commercial systems for some time, but is relatively new to the residential and small commercial sectors. Evapotranspiration-based irrigation controllers can be defined as controllers that save outdoor water use by monitoring and using information about site conditions (such as soil moisture, rain, wind, slope, soil, plant type, and more), and then applying the right amount of water upon those factors (Dukes, 2012). These irrigation controllers receive feedback from the irrigated system and then schedule or adjust irrigation duration and/or frequency accordingly.

ET controllers include: (i) evapotranspiration (ET) based irrigation controllers, (ii) Soil water sensor based irrigation controllers. In a soil water sensor based irrigation controllers, data from soil moisture sensor is used to allow or bypass timed irrigation events. ET controllers are divided into three subgroups according to the weather the controllers receive weather data. These groups are: i) Standalone Controllers, ii) Signal-Based Controllers, and iii) Historical-based controllers (Dukes et al., 2010). Standalone controllers use sensors installed on-site to measure weather site conditions and then calculate real-time ET0 based on the data collected. The sensors collect readings at intervals anywhere from every second to every fifteen minutes and then a daily ET0 is calculated from those values (Dukes et al., 2005). In Signal-based controllers, a wired (phone) or wireless (cellular or paging) communication is utilized to receive ET0 data. Weather information is gathered from publicly available or dedicated weather stations in the controller location range. Some manufacturers gather the climatic information data from the weather stations, calculate a daily ET0 value, and then broadcast the value directly to the controller each day (Dukes et al., 2005). Historical-based controllers depend on historical ET0 information for the area.

Typically, monthly historical ET0 is programmed into the controller by the manufacturer or installing contractor and then adjusted based on site specific weather measurements to better account for differences in current ET0 from historical trends (Dukes et al., 2005).

Devitt et al. (2008) found that water applied in Las Vegas homeowner landscapes was reduced by 20% on average when signal-based ET controllers were adopted compared to sites without an ET-based controller. Davis et al. (2009) reported that ET controllers had a great potential to save water by 42% when compared to a time-based irrigation schedule that does not take into account the real-time rainfall when replaces the net irrigation requirement and still maintain good turfgrass quality. Davis et al. (2007) conducted a study in Florida from 1 July 2006 to 30 November 2006 and found that two of three brands of ET controllers tested were capable of reducing water applied by 20–60% when they compared to a 2 days/week irrigation schedule with no irrigation control devices, while maintaining acceptable turf quality. McCready et al. (2009) compared two brands of ET controllers with the irrigation applied, based on the recommended irrigation rates to study the amount of irrigation applied and found that water savings ranged between 25% and 62%. The testing was conducted under dry to normal Florida rain conditions.

MATERIAL AND METHOD

Site description

A 1,000 m2 area located at educational farm of King Saud University, Riyadh- Saudi Arabia (24° 43’ N latitude, 46° 43’ E longitude, 635 m altitude)) was prepared, leveled and then divided into three main fields separated with buffer zones of 5 m. Each field was subdivided into three blocks, length and widths of these blocks were 10 and 7 m, respectively. Two commercially available controllers (Weathermatic SL1600 and Hunter Pro-C) were installed in first and second fields to irrigate and schedule irrigation automatically based on local climate conditions collected by the controller sensors and processed by intelligent system (Fig. 1). ET controllers were programmed using the manuals provided by manufacturers according to site-specific conditions. The blocks in the third field were irrigated and controlled manually by standard time-
based controller based on ETo values acquired from a nearby automated weather station. The climate parameters during the growth period of tomato crop are presented in Table 1. Physicals and chemicals soil properties during the experiment are summarized in Tables 2 and 3.

Fig (1) Simplified diagram showing how ET sensor is typically connected to an automated irrigation system: (a) the controller closes the switch, allowing irrigation because of hot conditions; (b) the controller opens the switch, bypassing irrigation because of rainfall conditions

Calculated irrigation time

The actual crop water use in third field (control) was determined by multiplying the calculated ETo by a crop coefficient, Kc (Eq. 1). Once the reference ETo has been determined, the actual operation time required for control treatment has been applied (Eq. 2) to start various time-based irrigation schedules on the real tomato crop.

\[
ET_c = ETo \times Kc
\]

\[
T = \frac{ET_c \times Kc \times A \times P_w}{Ea \times (1-LR) \times Q_s}
\]

where T is the actual operation time required (min), ETc is the crop water requirements (mm day\(^{-1}\)), ETo is the reference evapotranspiration (mm day\(^{-1}\)), Kc is the crop coefficient, A is the block area (m\(^2\)), Pw is a wetted area percentage (%), Ea is the application efficiency (%), LR is the leaching requirements (%) and Qs is the discharge from the irrigation system (lit/min).

Water use efficiency

The tomato yield and water use data were combined using equation 3 to give water use efficiency (WUE, Kg/m\(^3\)) in yield per volume terms (Howell, 2001).

\[
WUE = \frac{Yield (kg)}{Applied Water (m^3)}
\]

Agronomic traits

Two months after transplanting, random samples of three plants from each sub-plot were taken to measure vegetative growth (stem fresh weight, plant fresh weight, stem dry weight and plant dry weight). Leaf samples were collected, washed in distilled water and dried at 70°C in forced air-oven until the weight became constant (48-72 hours) to calculate the dry matter contents. Fruit yield components (fruit number per plant, average fruit weight/plant, early yield and the total yield) were determined. Fruit quality traits were also measured in which five fruit samples were collected, juiced, and filtered to measure fruit content of total soluble solids (%), vitamin C (mg/100g FW), and titratable acidity (%) (AOAC, 1995).

Experimental design

The irrigation treatments were established, T1 through T3, replicated three times for a total of nine blocks with a Randomized Complete Block design (RCBD) as follows: T1, Weathermatic SL1600; T2, Hunter Pro-C; and T3, a time-based treatment (Control). Least significant differences method (LSD) at 0.05 level was employed to evaluate the statistical effect of irrigation treatments. The SPSS 21 statistical package was used to evaluate the statistical differences between treatment means.

RESULT AND DISCUSSION

ET controllers

Evapotranspiration (ET) controllers have been used to schedule irrigation in tomato under surface drip irrigation system using Weathermatic SL 1600 and Hunter-Pro C. The cumulative irrigation depth added to all replications separately by Weathermatic (434.55, 432.84 and 429.15 mm), Hunter (427.28, 425.35 and 426.62 mm) and Control treatments (592.63, 588.33 and 597.93 mm) was plotted on weekly basis and shown in Figs. 2, 3 and 4. In these Figs, it is possible to observe that quantity of water applied had no statistical significance amongst replications under each treatment (their values were so close in all stages of the crop). Mainly because the dynamic irrigation scheduling for each group of replications was executed by the same controller. The regression analyses indicated that polynomial functions could be used to describe the relationships between the cumulative irrigation depth and crop growth period. Furthermore, the regression coefficient for all replications were more than 0.98, indicating a good model fit.

Fig (2)Accumulative irrigation depth added by Weathermatic for the three replicates

Fig (3)Accumulative irrigation depth added by Hunter for the three replicates
The average values of cumulative irrigation depths added by Weathermatic, Hunter and control treatments over the entire study period were 432.19, 426.42 and 592.96 mm, respectively. Correlation of cumulative irrigation depth with ET controllers and control treatment as seen in Fig. 5 showed that both ET controller’s values were close in all stages of crop. On the other hand, the control values were only close to ET controllers values in early stages and got quite large in the late season stages. It can be also seen the considerably water saving over the entire study period was obtained by Hunter (28%). Similarly, Weathermatic treatment reflected a similar trend to water savings with similar statistical results (27%) when it compared with control, but it was poorer than Hunter. This could be due to the differences in runtimes, irrigation frequencies and the number of irrigation events bypassed under Weathermatic, Hunter treatments. Additionally, the ET controllers showed a great potential to save water ranged from 38% by Weathermatic to 39 % by Hunter as compared to conventional irrigation methods (700 mm in average) practiced by the local framers in the area (MOA, 2012). This could be attributed to more accurately water estimated ET controllers, especially over cold months. The obtained results were found to be in agreement with (Grabow et al., 2010; Mayer et al., 2009; Devitt et al., 2008).

The cultivated tomato crop showed significant differences in agronomic traits (vegetative growth, fruit quality and fruit yield traits) in response to water applied by ET controllers and control treatment (Figs. 7, 8 and 9). From these tables, it can be depicted that the highest values of agronomical traits were found in Hunter and Weathermatic, respectively when they compared to control. This could be due to the appropriate use of surface drip and sensor-based irrigation systems that closely match the day-to-day water use of plants. The results of analysis indicated that values of Plant fresh weight (g), Plant dry weight (g), Stem fresh weight (g) and Stem dry weight (g) increased by 67% and 28.3%, 30.6% and 30%, 50.2% and 22.1%, 28.7% and 25.2% under Hunter and Weathermatic treatments, respectively compared to control treatment (Fig. 8). The values of Early yield (kg/m²), total yield (kg/m²), average fruit weight (g) and number of fruit per plant were also significantly increased by 50.5 % and 31.3 %, 50.4 % and 31.3 %, 41.9 % and 21.2 %, 53.8 % and 48 % under Hunter and Weathermatic treatments, respectively compared to control treatment (Fig. 9). This could be due to the appropriate use of surface drip and sensor-based irrigation systems that closely match the day-to-day water use of plants. These results were found to be in agreement with (Dorji et al., 2005; Fernandez et al., 2005; Jaimez et al., 2000).
CONCLUSION

This study was to evaluate the effect of two evapotranspiration-based irrigation controllers on the water savings and agronomic parameters of tomato crop under surface drip irrigation system. Experimental site was located at educational farm of King Saud University, Saudi Arabia on a sandy loam textured soil. Two ET controllers were tested: Weathermatic SL1600; Hunter pro C. The findings indicated that both ET controllers, Weathermatic SL1600 and Hunter pro C applied water less than water scheduled by time-based controller (control). In details, ET controllers showed a potential to save water ranged from 27% by Weathermatic SL1600 to 28% by Hunter pro C as compared to control treatment. Moreover, irrigation savings can be more highly during normal Saudi Arabia rainfall conditions for properly installed and programmed ET controllers. The highest water use efficiency and agronomical characteristics (vegetative growth, fruit quality and fruit yield traits) were found in Hunter pro C and Weathermatic SL1600 treatments, respectively and the lowest one was found in control treatment.

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