EFFECTS OF SCHEDULING TECHNIQUES OF WATER APPLICATION FOR DRIP IRRIGATION SYSTEM ON TOMATO YIELD IN ARID REGION

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Abstract

Irrigation is necessary in order to produce tomato in arid region such as Saudi Arabia, with limited water supplies. Drip irrigation (DI) is being adopted in these areas to conserve water under economical crop production. Field experiment was carried out to study effects of different irrigation scheduling management strategies on fruit yield and quality of drip irrigated fresh market tomatoes, water use efficiency and irrigation application efficiency. The experiment included three scheduling methods, which were used to irrigate tomato field: Evapotranspiration (ET) controller, soil moisture sensor (watermark sensor) and control treatment based on weather data. All irrigation-scheduling methods were effective, prescribing different amount of water for a given season. Irrigation amount increased from 841.5 mm (ET controller) to 882.60 mm (watermark sensor) and 1034.33 mm (control treatment), during two seasons. Both WUE and IWUE increased with decrease in irrigation water depth. The maximum average WUE (7.26 kg-m^{-3}) and IWUE (4.66 kg-m^{-3}) values were for ET controller as average, during the two seasons. In addition, ET controller method conserved up to 7 % and 18% water compared to the watermark sensor and control treatments, respectively. Based on the above results, it is recommended that if the tomatoes are well irrigated based on ET controller, the farmer can get higher tomato yield in areas experiencing severe drought, such as Saudi Arabia.

Keywords: water use efficiency, water application efficiency, automatic irrigation

INTRODUCTION

Water scarcity and drought are the major factors constraining agricultural crop production in arid and semi-arid zones of the world. Innovations for saving water in irrigated agriculture and thereby improving water use efficiency are of paramount importance in water-scarce regions. Therefore, use of new irrigation technologies in agriculture has aimed at increasing crop production. New developments in irrigation technologies have a great importance. Efficient use of water by irrigation system is becoming increasingly important, and drip irrigation (DI) may contribute substantially to the best use of water for agriculture, improving irrigation efficiency (Sezen *et al.*, 2006). Therefore, adoption of modern irrigation techniques must be emphasized to increase WUE. These modern techniques must result in efficient water delivery and high productivity while minimizing water use (Acar *et al*., 2010).

In the arid and semi-arid areas, DI is frequently used to reach the maximum water use efficiency (Fabeiro *et al*. 2002). DI has been used in horticultural operations since the middle of the 20th century (Hillel, 2008) and conventional drip irrigation is considered one of the most efficient irrigation systems. DI has the potential to use scarce water resources most efficiently to produce vegetables (Locascio, 2005). However, DI is an irrigation system whereby water is supplied under low pressure directly treating only to the plant roots (Nautiyal *et al*., 2010). DI is the most effective way to save water by using water more efficiently to increase crop yield and improve the irrigation uniformity (Schwankl and Hanson 2007 and Zotarelli *et al*., 2009).

DI can distribute water uniformly, precisely control irrigation volumes, increase plant yields, reduce evapotranspiration (ET) and deep percolation, and decrease the danger of soil degradation and salinity (Batchelor *et al*., 1996; Karlberg and Frits, 2004). The trend in recent years has been toward the conversion of surface irrigation to DI to improve plant quality and yield. Currently, some farmers are not aware of when they should irrigate and how much water they should use under drip irrigation conditions. They tend to use irrigation timing and volumes according to conventional experience, and then induce new water loss under new technology. Therefore, easy-operation irrigation scheduling methods are very stringent with respect to tomato drip irrigation conditions.

Earlier studies have shown that DI is the most suitable method for vegetable crops and it is possible to increase WUE by modern irrigation scheduling methods, such as cucumber (Yuan *et al*., 2006), eggplant (Aujla *et al*., 2007), potato (Erdem *et al*., 2006), and tomatoes (C¸etin and Uygan, 2008). Many studies comparing sprinkler or furrow irrigation with DI in tomatoes and in other crops have shown that DI generally resulted in higher WUE and crop yields (Singandhupe *et al*., 2003).

Irrigation events may be scheduled based on: measured soil moisture, climatic parameters and estimated evapotranspiration (ET) coupled with crop coefficient specific to the region. Many methods of irrigation scheduling have been proposed in order to measure the amount of water use by a crop. There are three methods for matching irrigation with crop water requirements: the weather-based methods using ETr (Allen *et al*. 1998), the soil water-based methods using soil moisture sensors (Evett 2008), and the soil–water balance calculations and plant stress-sensing techniques (Jones 2004).

There are a variety of techniques can be used to reduce water use (McCready, *et al*., 2009). These techniques include ET control devices and soil moisture controllers. Mayer *et al*. (2009) found that ET controllers reduced irrigation by 6.1%; and it was found that 56.7% of the sites were responsible for a significant decrease in irrigation application, while 41.8% were responsible for a significant increase. Davis *et al*. (2010) demonstrated that the ET controllers applied only half of the irrigation calculated for the theoretical requirement for each irrigation event, and irrigation adequacy was decreased when the ET controllers were allowed to irrigate any day of the week. Davis and Dukes (2012) found that ET controllers can match irrigation application with seasonal demand and in particular reduce irrigation in the winter when plant demands are dramatically reduced. In addition, they indicate that when ET controllers are applied to sites irrigating at levels less than plant demand, those controllers will likely increase irrigation.

The automation of DI systems with ET controllers or soil moisture sensors may further improve WUE. Automated irrigation systems have functioned successfully (Shock *et al*., 2002). The development of automated site-specific drip irrigation systems allows producers to maximize irrigation efficiency, while minimizing negative productivity effects. The adoption of modern water-saving technology is often cited as a key to increasing WUE while maintaining current levels of production (Comprehensive Assessment of Water Management in Agriculture, 2007). However, this technology has not been tested on field crops in a hyper-arid region such as Saudi Arabia. Such systems can be used to determine crop yield and evaluate responses to irrigation criteria, in order to evaluate crop performance.

Automation of DI systems based on evapotranspiration controllers or soil moisture sensors may further improve WUE. Development of automated site-specific drip irrigation systems allow producers to maximize irrigation efficiency, while minimizing negative effects on their productivity (Shock *et al*., 2002). Adoption of modern water-saving technology is often cited as a key to increasing WUE while maintaining current levels of production (Comprehensive Assessment of Water Management in Agriculture, 2007). Though, this technology has not been tested with field crop in a hyper arid region such as Saudi Arabia, yet such systems technique can be used to determine crop yield and performance to irrigation criteria. The objectives of this study were to compare the effects of different scheduling technique management strategies on 1) the fruit yield and quality of drip-irrigated fresh market tomatoes, 2) WUE, and 3) application efficiency.

MATERIALS AND METHODS

During the two seasons of 2016 and 2017, the experiments were conducted at the Experimental Farm of the College of Food and Agriculture Sciences of King Saud

University, Riyadh (24°43′ N latitude, 46°43′ E longitude and 635 m altitude). The experimental site was irrigated by a surface drip irrigation system. Before the start of the experiment, soil samples were collected from different locations in the field to determine soil physical properties. Locations were selected to represent the dominant soil conditions in the field. Three soil samples were taken from the field at three different depths (0–20, 20–30 and 30–60 cm) to determine soil texture. The soil was loamy sand (85.9% sand, 6% silt and 8.1% clay).

Surface drip irrigation systems were installed in the field. Buffer zone of approximately 3 m separated each plot to reduce interactions between the treatments. The DI system consisted of 16 mm inside diameter (I.D.) thin-wall lateral drip lines with welded-on emitters (built in R, 50 cm dripper spacing) with a nominal emitter discharge of 4 L h^{-1} at a design pressure of 200 kPa. Drip lines were buried 25 cm deep directly under the soil beds in plots 1, 2 and 3 Fig. (1a). After the ID installation, the soil surface was leveled and firmed. Irrigation amounts were metered separately in each plot using commercial municipal-grade flow accumulators. The irrigation duration varied among treatments because of the three different methods of irrigation scheduling. The hydraulic aspects of the design for each system were aimed to give uniform application of irrigation water.

The uniformity of water application for each scheduling method below the soil surface through the soil profile was determined by measuring gravimetric moisture contents from soil samples taken 24 and 48 hours after irrigation. The samples were collected parallel and perpendicular to the lateral line at distances of 0, 5, 10, 15, 20 and 25 cm from the emitter location as shown in Fig. (1b). The gravimetric soil samples at each depth (0, 10, 20, 30, 40, 50 and 60 cm) were repeated three times after irrigation (24 and 48 hr). These measurements were taken from each plot three times during mid-season of tomato crop.

Three methods of irrigation scheduling were used to determine the duration and amount of water to be applied to a tomato crop by surface drip irrigation system. The irrigation scheduling in plot 3 was controlled by evapotranspiration controller (ET controller). The ET-based controllers consider weather based parameters when determining irrigation events. Depending on the manufacturer, each controller functions differently but typically can be programed with various conditions specific to the field. These conditions can include soil type, plant type, root depth, sun and shade, etc. The ET controller has the ability to add water to the crop when it was needed based on controlled evapotranspiration and weather data. The controller

(Hunter pro-c)[1] was purchased locally and was programed according to site specific conditions. Plot 2 was controlled by automatic watermark soil moisture sensors. The initiation and termination of irrigation in the scheduling technique was based on soil moisture measured by watermark sensors installed at 5 cm above the drip line.

Automatic scheduling for plot 2 was set at 10% soil moisture content as the lower limit and 15% as the upper limit (on – off). The scheduling treatment in plot 1 (control treatment) was manually irrigated based on weather data collected from an automatic weather station installed at the experimental site. Penman–Monteith equation was used to calculate evapotranspiration (ET). Each plot was approximately 4.5 m wide and 7 m long and had 5 rows of drip lines spaced 0.9 m apart running from west to east. Tomato plants were spaced 0.50 m apart in each row. The 5 drip lines in each plot were connected to a common sub-main irrigation line at the inlet side of the plot; and a common flush line and flush valve at the distal end of the plot Fig. (1a).

Tomato plants (Solanum lycopersicum Mill. var. Nema) were transplanted to the fields on 14 February 2016 and 7 February 2017. The irrigation processes were terminated on 9 April 2016 and 14 April 2017 for the first and the second season, respectively.

Water use efficiency and distribution uniformity

Irrigation water used efficiency (IWUE) is the ratio between the total fresh yield (FY) and the seasonal applied irrigation water (Dg)t (Michael, 1978). While, water use efficiency (WUE) is the relationship between the yield and the ETc (Wanga *et al.*, 2007). WUE and IWUE were calculated using Equations 1 and 2, respectively.

$$WUE = \left(\frac{Y}{ETc} \right) \tag{1}$$

$$IWUE = \left(\frac{Y}{(D\,g)_t} \right) \tag{2}$$

In these equations, Y is the economical yield (kg), ETc is evapotranspiration (mm), and (Dg)t is the total amount irrigation water (mm) during the crop season.

To calculate the ETc and the irrigation water requirement of tomato, daily ETo values were first determined using the meteorological data and then multiplied by the crop coefficient. The irrigation system in each plot was operated based on the scheduling method used; turned on and off manually in the control treatment and automatically in ET controller and watermark sensor treatments. The depths of

[1] The use of the trade name does not imply promotion of this product; it is mentioned for research purposes only and providing specific information and does not imply recommendation or endorsement.

irrigation water (Dg) applied in each irrigation event for all plots were calculated separately from the differences of flow meter reading before and after irrigation.

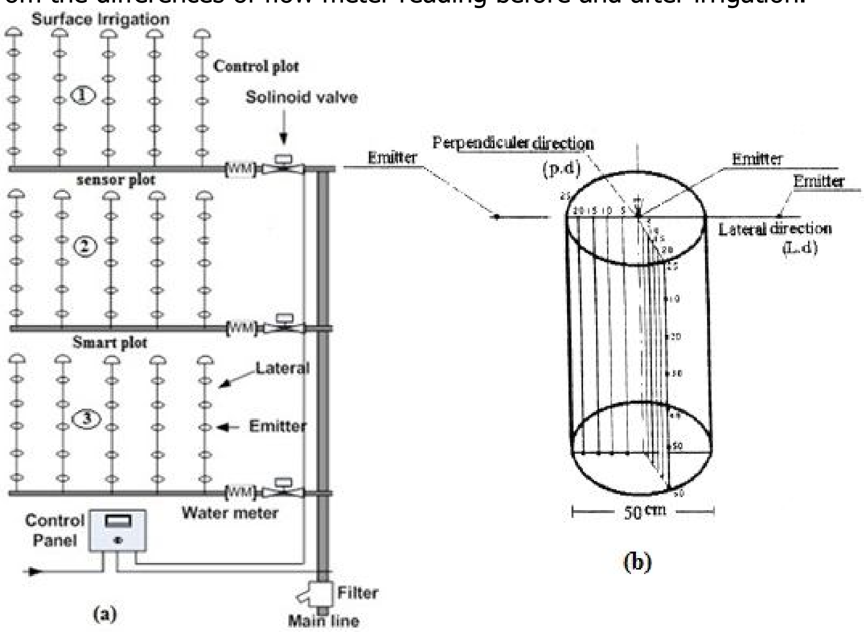

Fig. 1. Field experimental layout (a) and diagram showing sampling for soil moisture contents parallel and perpendicular to the direction of the irrigation line (b).

Assessment of the uniformity of water redistribution in the soil profile

The coefficient of uniformity by Christiansen (1942) was calculated by using soil gravimetric moisture contents measured at seven soil depths (0, 10, 20, 30, 40, 50, and 60 cm), and at different distances from emitter (10, 15, 20 and 25 cm in parallel and perpendicular directions to the drip line, as shown in (Figure.1b). The soil water contents were measured 24 and 48 hours after irrigation was ceased. The evaluation tests were carried out four times starting from the beginning until the end of season. The following equation was used to evaluate the uniformity (Cus) of water redistribution below the soil determined gravimetrically:

$$Cu_S = 100\left(1 - \frac{\sum\left|\theta_i - \bar{\theta}\right|}{N\,\bar{\theta}}\right) \qquad (3)$$

$$\bar{\theta} = \left|\sum_{i=1}^{N} \theta_i\right| / N$$

where

Cus = Christiansen’s coefficient of uniformity of soil water content below soil surface

θi = the measured gravimetric soil water content at depth i

$\bar{\theta}$ = the mean gravimetric soil water content, and

N = number of measured points (soil depth).

RESULTS AND DISCUSSION

Crops evapotranspiration (ETc)

The daily and weekly averages of the ETc for tomato crop in control treatment (plot 1) were calculated using the daily climatic records during the two growing seasons (Table 1). The values of ETc were estimated by the product of the reference evapotranspiration (ETo) and the crop coefficient (Kc) according to FAO 56, the trends in Kc during the growing period that is divided into four crop development stages (initial, rapid development, mid-season and late season) of tomato crop. From this table, it can be concluded that ETc values were small in early 2 weeks and then increased with the development of plants.

Table 1. Average weekly ETc for a tomato under a surface drip system for control treatment during the two seasons.

Growth Period (week)	ETo (mm/d)	Kc	ETc (mm/d)	growth stages
1	4.22	0.70	2.95	Initial
2	4.65	0.70	3.25	
3	4.98	0.70	4.54	
4	5.56	1.15	6.39	rapid development
5	5.61	1.15	6.46	
6	5.78	1.15	6.64	
7	5.28	1.15	6.08	
8	5.92	1.15	6.30	
9	6.71	1.15	6.84	
10	6.67	0.90	6.00	mid-season
11	6.54	0.90	5.89	
12	6.87	0.90	6.18	
13	6.56	0.90	5.53	
14	6.64	0.90	5.53	
15	7.49	0.75	6.74	Late Season
16	6.96	0.75	5.22	
17	7.17	0.75	5.38	
Avg.	Average ETc (mm/day)		5.64	
Sum	Total ETc/season (mm)		671.57	

Irrigation management

The averages of weekly and seasonal total water applied (m^3), irrigation depth (Dg) and the accumulated (Dg)t to the tomato crop by three scheduling technique (ET controller, automatic watermark and control treatments) are presented in (Table 2). It can be observed that the average total amount of water added during crop season were 10.60 m^3, 11.12 m^3 and 13.03 m^3 in ET controller, automatic watermark and control treatments, respectively. There was water saving of 4.68% and 18.65% in ET controller treatment compared to other two treatments, respectively. Also, watermark sensor technique used less water by 14.66% compared to the control treatment.

Consequently, the use of ET controller or watermark methods conserves water and this superiority in saving water may be due to the fact that the two methods have the feature of increasing or reducing irrigation water automatically according to the plant needs compared to the control treatment.

Table 2. Averages of irrigation water depths applied to tomato crop during two seasons for different scheduling methods.

Growth Period (week)	ET controllers – plot 3			Watermark sensor – plot 2			Control treatment – plot 1		
	Water Added (m^3)	Irrigation Depth Dg (mm)	Acc. Depth (Dg)t (mm)	Water Added (m^3)	Irrigation Depth Dg (mm)	Acc. Depth (Dg)t (mm)	Water Added (m^3)	Irrigation Depth Dg (mm)	Acc. Depth (Dg)t (mm)
1	0.47	37.23	37.23	0.60	47.90	47.90	1.33	105.60	105.60
2	0.43	34.40	71.63	0.44	34.56	82.46	0.79	62.76	168.36
3	0.42	33.44	105.07	0.54	42.66	125.12	0.64	50.96	219.32
4	0.45	35.60	140.67	0.59	46.83	171.94	0.82	65.46	284.78
5	0.61	48.28	188.95	0.53	42.10	214.04	0.60	47.61	332.38
6	0.30	24.06	213.01	0.22	17.67	231.71	0.27	21.13	353.52
7	0.30	24.13	237.13	0.15	11.70	243.40	0.66	52.06	405.58
8	0.56	44.83	281.97	0.57	45.07	288.48	0.80	63.49	469.07
9	0.92	73.10	355.06	0.47	37.63	326.10	0.74	58.98	528.05
10	0.29	22.63	377.69	0.88	69.91	396.02	0.77	61.10	589.14
11	0.67	53.17	430.86	0.59	46.93	442.94	0.73	58.02	647.16
12	0.89	70.63	501.49	0.90	71.48	514.43	0.73	57.56	704.72
13	0.96	76.58	578.07	0.53	42.22	556.65	0.79	63.00	767.72
14	0.67	53.21	631.29	0.85	67.60	624.25	0.77	61.26	828.98
15	0.89	70.29	701.57	1.00	79.13	703.38	0.71	56.10	885.09
16	0.86	68.03	769.61	0.82	64.69	768.07	0.80	63.43	948.52
17	0.91	71.90	841.51	1.44	114.53	882.60	1.08	85.81	1034.33
Sum	10.60	841.51		11.12	882.60		13.03	1034.33	

Agronomical characteristics

This study revealed that both irrigation-scheduling techniques had a clear impact on the agronomical characteristics of the plants as shown in (Table 3). In the same context, it was found that the average yields for the two seasons were 39.22, 35.35 and 30.23 ton ha^{-1} in the ET controller, automatic watermark and control methods, respectively. This shows that the variation between the yields in the ET controller between automatic watermark and control treatments was 10 to 23%, respectively. Meanwhile, the agronomical data (Table 3) for the ET controller treatment reveled a significant difference in plant height (cm), number of branches, fruit length (cm), average fruit weight (g), total yield (Kg. m^{-2}), total yield (ton ha^{-1}) and WUE/IWUE (Kg. m^{-3}) compared to the automatic watermark and control treatments.

Table 3. Average tomato growth responses to irrigation treatments during the two seasons.

Character	Treatment		
	Smart ET	Sensor	Control
Plant height (cm)	49.6٠	48.40	53.20
Number of branches	5.31	5.24	5.12
Fruit length (cm)	5.62	5.7٠	6.44
Fruit dia. (cm)	5.18	5.07	5.2٠
Fruit shape index	1.28	1.25	1.23
Avg. fruit wt.(g)	92.3٠	91.8٠	88.9
Early yield (ton ha^{-1})	22.23	20.15	23.04
Total yield (ton ha^{-1})	39.22	35.35	30.23
WUE (kg m^{-3})	7.26	6.08	4.50
IWUE (kg m^{-3})	4.66	4.01	2.92

Water use efficiency

Table 4 demonstrates the effects of the three scheduling techniques (ET controller, automatic watermark and control treatments) on tomato WUE during the growing seasons. The data in Table 4 revealed that the values of WUE and IWUE were higher in the ET controller treatment. The tomato yield, in the case of ET controller treatment, was higher (39.22 ton ha^{-1}) compared to the yield in the two other scheduling methods (Table 3). Similar trend was observed for WUE and IWUE. The maximum and minimum values of WUE and IWUE for ET controller methods were 7.26 and 4.66 (kg .m^{-3}), while WUE and IWUE for watermark and control methods were 6.08, 4.01 and 4.50, 2.92 (kg. m^{-3}), respectively (Table 4). However, the results indicated that irrigation water was used more effectively through ET controller treatment.

Table 4. Average WUE and IWUE under different scheduling methods during the two seasons

Irrigation treatments	Drip irrigation					
	ETc		AIW		WUE (kg m^{-3})	IWUE (kg m^{-3})
	(mm)	m^{-3} h^{-1}	(mm)	m^{-3} h^{-1}		
Smart ET	540.42	5404.20	841.51	8415.1	7.26	4.66
Sensor	581.23	5812.30	882.60	8826.0	6.08	4.01
Control	671.57	6715.70	1034.33	10343.3	4.50	2.92

The Table 4 shows that the highest and lowest values of IWUE for tomato crop were 4.66 and 2.92 (kg. m^{-3}) in ET controller and control treatments, respectively. The increase of IWUE value was 37.34% for ET controller compared with the control treatment. In contrast, the smallest amount of irrigation water was 540.42 mm during the entire season in ET controller treatment, while the largest amount was 671.57 mm in control treatment. Data in Tables (3 and 4) indicated that scheduling method of ET controller gave the highest values of total yield, WUE and IWUE and applied less irrigation water compared to watermark sensor method and control method, respectively.

The lower amounts of water used with ET controller method correspond inversely to higher WUE. This agrees with the results by Faberio *et al*. (2002), Topak *et al*. (2011), and Almarshadi and Ismail (2011). Similar findings were also obtained by Wan and Kang (2006), who found a low irrigation frequency. The decreased values of WUE and IWUE under the watermark sensor and control methods can be attributed to the increasing level of applied irrigation water. Under conditions of the three irrigation treatments in the both growing season, ET controller resulted in the highest values of WUE and IWUE, followed by watermark sensor and then control treatment. It was apparent that the WUE and IWUE of tomato decreased with more water applied in irrigation.

Uniformity of water distribution

The water redistribution patterns under drip irrigation systems for the three scheduling methods were determined at different depths below the soil surface, as shown in Fig. (2). The Table 5 and Figure 2 show the average of uniformity coefficient (Cus) and patterns for Cus in parallel and perpendicular locations to the drip line at different depths for each scheduling method after 24 and 48 hour from irrigation was ceased. The highest uniformity was obtained in the control treatment and the lowest with ET controller treatment for 24 and 48 hours after irrigation. Generally, the average values of Cus of control scheduling technique were higher than those of both ET controller and automatic watermark systems at any depth of soil profile and time of measurements (24 and 48 hour).

However, in general, the water within the soil profile at any depth was uniformly distributed through soil profile. This can be explained by the hydraulic gradients within the irregularly wetted soil, which causes water movement within the soil profile parallel and perpendicular to the irrigation lines, resulting in the water movement within the soil to be more uniformly distributed. Also, the results showed that the average of Cus values were 81.62% for ET controller, 86.45% for watermark sensor and 92% for control treatment. Also, the values of Cus were decreased slightly with the increase in soil depth Fig. (2) due to the soil diffusivity, but increased with the time of measurements due to the accomplishment of equilibrium within the soil (Al-Ghobari, 2004).

In general, the Cu values were low in depths near the soil surface and increased with depth for all scheduling methods. However, this increase with depth was higher in control treatment compared to the increase in ET controllers and automatic watermark scheduling techniques Fig. (2).

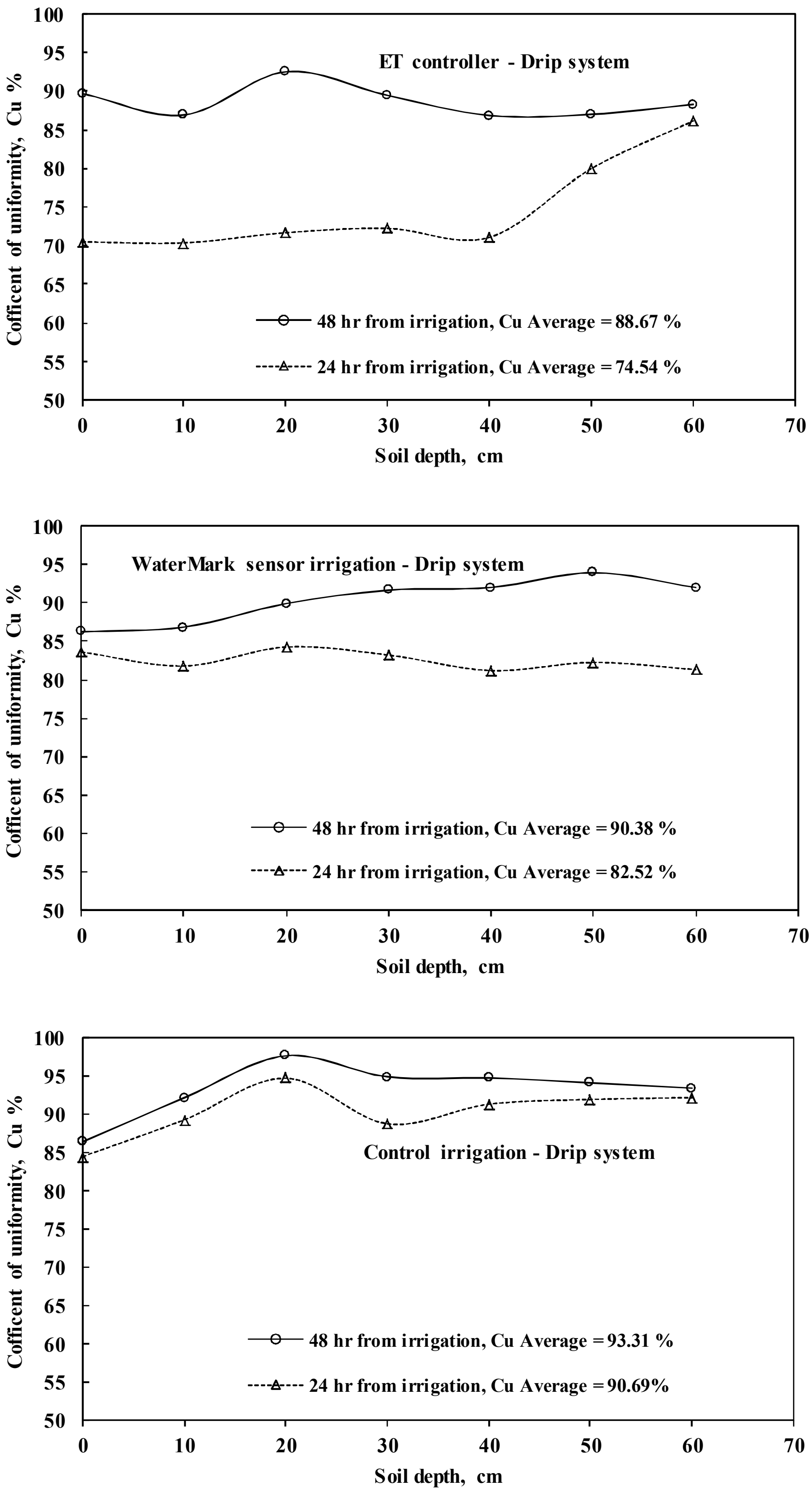

Fig. 2. Values of Cus as a function of soil depth after 24 and 48 hours of irrigation, for the three irrigation-scheduling methods

CONCLUSION

This study concludes that the ET controller methods offered a significant advantage in managing the irrigation of tomato crops in both seasons (2016 and 2017) under severely arid conditions. In compression with the other treatments, the ET controller significantly reduced water use by 18%. Consequently, water was used most commendably with the ET controller treatment. It was also found that the values of yield, WUE and IWUE were superior with ET controller compared to corresponding values in automatic watermark and control treatments.

The coefficient of uniformity for control treatments was 10.4% higher than for ET controller irrigation scheduling method, while variations in Cus values were not significant among the three scheduling techniques. ET controller technique gave the best crop yield, WUE and IWUE.

These results indicate the importance of adopting ET controllers, because of their effectiveness in providing irrigation water. This requires extraordinary effort, particularly in arid regions that suffer from water shortages, such as Saudi Arabia. The results presented here relate to the outcomes of the ET controller with respect to water management, crop performance, and water conservation. Moreover, this system will improve irrigation practices and ultimately minimize labor efforts. It can be concluded that there was an economic advantage when applying advance scheduling irrigation techniques using drip irrigation system with ET controller under arid conditions, such as Saudi Arabia.

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تأثير تقنيات جدولة تطبيقات المياه لنظام الري بالتنقيط على محصول الطماطم في المنطقة الجافة

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في ظل إمدادات المياه المحدودة بالمناطق الجافة حيث الظروف السائدة، أصبح الري من الأولويات الضرورية للاستخدام الأمثل لمصادر المياه لإنتاج محصول الطماطم بالمناطق القاحلة مثل المملكة العربية السعودية لتحقيق التنمية الزراعية المستدامة. وعليه يعتبر نظام الري بالتنقيط من انظمة الري التي يتم الاعتماد عليها بتلك المناطق للحفاظ على المياه و الإنتاج الاقتصادي للمحاصيل. أجريت تجربة حقلية لدراسة تأثيرات استراتيجيات إدارة جدولة الري المختلفة علي الاحتياجات المائية على محصول وجودة الطماطم، والتوفير في المياه المستخدمة وكفاءة استخدام المياه (WUE) وكفاءة استخدام مياه الري (IWUE) وكذلك حساب معامل انتظامية توزيع المياه الأرضية بعد الري لفترات ٢٤ و ٤٨ ساعة. وشملت التجربة ثلاث طرق مختلفة لجدولة الري بالتنقيط السطحي علي الاحتياج المائي (ET_o)، استخدمت في ري حقل الطماطم: استخدام نوعين من تقنيات التحكم الآلي مع نظامي الري بالتنقيط السطحي.

[(ET Controller) and (Automatic WaterMark soil sensor)] مقارنة بالري بنظام الري التقليدي

(Control - was manually irrigated based on weather) على اساس قيم البخر – نتح المحسوب (ET_o)باستخدام البيانات المناخية من محطة الطقس الكائنة بموقع الدراسة. أظهرت النتائج أن جميع طرق جدولة الري فعالة، حيث تم حساب متوسط الكميات المياه المضافة للطرق الثلاث المستخدمة خلال موسمي النمو. كما اوضحت النتائج زيادة عمق ماء الري المضاف حيث كان ٨٤١,٥١، ٨٨٢,٦٠ و ١٠٣٤,٣٣ مم للثلاثة طرق المستخدمة لجدولة الري بالتنقيط السطحي لكل من تقنية التحكم الآلي باستخدام (ET Controller)، والتحكم الآلي باستخدام (Automatic WaterMark soil sensor) و الري التقليدي (Control treatment)، بالترتيب خلال موسمي الدارسة. كما بينت النتائج أن كفاءة استخدام المياه (WUE) وكفاءة استخدام مياه الري (IWUE) تزداد كلما يقل عمق مياه الري. اشارت النتائج إلى أن كفاءة استخدام المياه (WUE) وكفاءة استخدام مياه الري (IWUE) القصوى لكلا الموسمين كانت (٧,٢٦ و ٤,٦٦ كجم/متر$^{-3}$) باستخدام تقنية التحكم الآلي (ET Controller). وبالإضافة إلى ذلك، أشارت النتائج إلى أنه مع استخدام تقنية التحكم الألى (ET Controller) لجدولة الري تم توفير في كميات المياه الري المستخدمة بنحو يصل إلى ٧٪ و ١٨٪ من المياه مقارنة مع جدولة التحكم الآلي باستخدام (Automatic WaterMark soil sensor) و الري التقليدي (Control treatment)، بالترتيب خلال موسمي الدارسة. و استنادا إلى النتائج المذكورة أعلاه، يمكن التوصية بانه إذا تم ري محصول الطماطم باستخدام تقنية التحكم الآلي (ET Controller) يمكن للمزارعين الحصول على أعلى محصول مع زيادة الحفاظ على المياه و خصوصا في المناطق التي تعاني من الجفاف الشديد مثل المملكة العربية السعودية.