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Effect of Irrigation Systems and Mulching on Summer Squash (*Cucurbita pepo* L.) Production in Semi-Arid Areas

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ABSTRACT

This study aimed to investigate the effect of two irrigation systems (surface drip *SDI* and subsurface drip *SSDI*), two types of soil plastic mulching (black plastic mulching *BPM,* and transparent mulching *TM)* plus a control treatment (no mulching *C*), and five levels of Elapsed time from germination to harvest (*ETime*); 58 days, 65 days, 72 days, 79 days & 86 days on the yield, growth parameters and water use efficiency (*WUE*) of summer Squash. The total fruit weight was almost the same for all treatments, but the distribution of fruit throughout the season were affected by the availability of excess water due to less evaporation caused by *SSDI* and the mulching. The maximum values of *WUE* were 2.01 kg /m^3 for the treatment with *SSDI* and *BPM* treatment. This treatment shortened the growing season and gave most of the plant fruit production between 65 and 75 days elapsed time since transplanting *ETime*. The maximum fruit production was for the treatment with *SD* and *TM.*

Keywords: surface drip, subsurface drip, black mulch, transparent mulch, water use efficiency, summer squash.

INTRODUCTION

Summer squash (*Cucurbita pepo* L.) is grown in many arid and semi arid regions, ranking high in economic importance among vegetable crops worldwide. Squash is considered one of the most important vegetable crops in the world as a commercial crop for open fields and greenhouses. The Middle East and Mediterranean countries, led by Turkey, Italy, and Egypt are producing one-third of the world's production (Paris, 1996). Summer squash is produced in most Mediterranean countries as one of the main vegetables (Mohammad, 2004) and is also a widely grown and consumed vegetable in Saudi Arabia. The cultivated area of summer squash in open field was 2483 hectares in 2016 and production was 44672 tons, while the cultivated area of greenhouses was 151 hectares and the production were 12231 tons (MEWA, 2017). Squash is grown during spring and summer seasons in open fields, while in winter it is grown under plastic tunnels. Drip and furrow irrigation are both used (Amer, 2011). Kuslu *et al.* (2014) reported that the amount of irrigation was a very important factor in determining the amount and the quality of the fruits in summer squash. Khalil *et al* 1996 reported that summer squash under drip irrigation had significantly higher growth yield and seed production than under furrow irrigation. Amer (2011) found that the total yield of squash was significantly higher using drip irrigation compared to the furrow irrigation. El-Gindy *et al.* (2009) found that subsurface drip irrigation gave the best moisture distribution in the root zone resulting in better root development and yield in summer squash. Ahmed *et al.* (2017) also found that the yield of squash and water use efficiency were higher under subsurface drip irrigation than of surface drip irrigation.

Mulching is the practice of covering the soil around the plant to reduce soil evaporation, conserve soil moisture, and increase or decrease soil temperature. There are several benefits of plastic mulches including early yields, and better fruit quality. These advantages of mulching in vegetable production have been attributed to the increases in soil temperature, the control of soil moisture and nutrients by reducing the soil evaporation and leaching of nutrients (Steinmetz *et al.*2016). A wide variety of colored plastic mulches with different spectral and physical properties is now available. Black and clear plastic mulches have been the most popular mulches. The most distinguished features of black mulches are high soil temperatures and weed control. Nonetheless, the clear plastic allows visible light to penetrate the film, condensation of vapor on the underside traps infrared radiation and soil temperature are significantly greater than with black plastic. However, herbicides are necessary for weed control with clear plastic (Steinmetz *et al.*2016). He also mentioned that on the long run, mulching could cause soil degradation, or the measures taken to prevent such problems would cause the mulching to be uneconomical.

Plant response depends on the thermal properties of the plastics. The effect on plant growth is associated with the capacity of these materials to absorb and transmit solar radiation. The plant environment is altered according to the wavelength, and the radiation reflected and transmitted from the mulch to the plant and the weed and pest control is in relation with the wavelength of the radiation passing through the mulch (Johnson and Fennimore, 2005). The main purpose of using soil cover in Saudi Arabia is conserving soil moisture by preventing or limiting evaporation.

Water is a critical and vital factor for plant growth, yield and quality. Squash as well as other vegetable crops are very sensitive to water deficit (Nadler and Heuer, 1995). Successful management of irrigation water is necessary to achieve a high yield (Foti *et al.*, 1995). Economic use of water is a major problem to deal with in irrigated areas of arid and semi-arid regions. Giving the exact amounts of irrigation is essential to obtain economical yields of different crops (Brown, 1999). Drip irrigation is the most common irrigation methods for vegetable crops in Saudi Arabia, while sub-drip irrigation is considered a promising technique for irrigation in sandy and loamy soils. The agricultural sector in Saudi Arabia consumes about 78% of the national fresh water use. Squash is usually grown in Saudi Arabia during fall and spring seasons and are very sensitive to low temperature and frost. Successful irrigation of squash requires knowledge of both irrigation and scheduling methods. It is recommended that a continuous water supply from squash germination to maturity and harvesting is needed for successful and economical production. Thus, the aim of this investigation was to evaluate the effect of irrigation systems, soil plastic mulching, and Elapsed time from germination to harvest on squash growth, yield, and water use efficiency.

MATERIALS AND METHODS

The present study was conducted in 2018 at the Experimental station of the College of Agriculture and Veterinary Medicine, Qassim University, Al-Qassium region (latitude 26-27 N, longitude 44-45 E, altitude 725 m above sea level), Kingdom of Saudi Arabia. Soil samples were collected prior to planting at 0-20 cm depth and the average values of their properties were given in Table (1). The values of P^H and EC of irrigation water were 7.1 and 1.5 dS/m respectively. Plots were arranged in a randomized complete block design. Plants were arranged in plots with 50 cm between rows and 30 cm between plants in the row with 2 empty rows separating planted rows. Figure 1 shows the experimental layout. Lana cultivar of squash produced by SPS Dorsing Seeds Inc. USA was used in this study. A GR micro drip line with in line 3.0 L/h pressure compensating emitters with 50 cm spacing in-between with a single emitter per plant arrangement for both the surface and subsurface irrigation systems. Each emitter line was equipped with a valve to control its flow. Each treatment was equipped with a flowmeter to determine the total amount of water per irrigation. The amounts of the irrigation water were the same for all the treatments and were calculated according to FAO 56 water requirement method (Allen *et al.* 1998).

Table 1. Some physical and chemical properties of Experimental soil samples

Property		Value
Sand (%)		92.3
Silt (%)		3.8
Clay (%)		2.9
Texture		sandy
pH[1]		7.64
Macro-Nutrient (mg/kg)	Total N	15
	P	16.5
	K	36

1- pH was measured in the extract of saturated soil paste.
2- Total N was determined by Kjeldahal method; P was extracted using Olsen method; K by 1 N NH4OAc at pH 7.

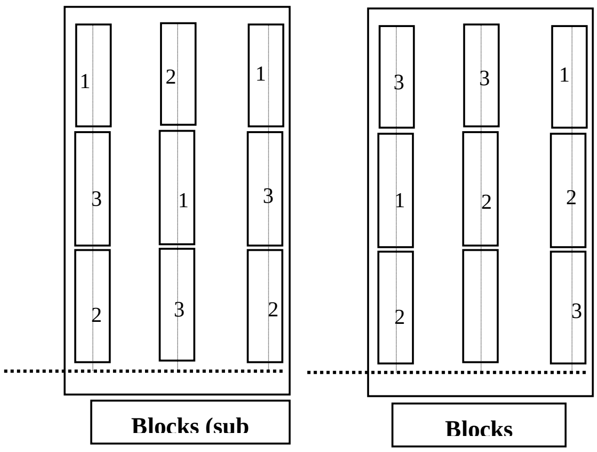

Figure 1. Experimental layout

Summer squash seeds (cv. Lana) were sown on 01 February 2018. The field experiment was a factorial experiment in complete randomized design (*CRD*).

For determining the effect of irrigation system, mulching, and elapsed time from germination on some agronomic parameters.

Treatments:

1. Irrigation system (*Irri*)

(1) Surface drip irrigation (*SDI*), (2) subsurface drip irrigation (*SSDI*).

2. Mulching (*Mulch*)

(1) No Mulching (*C*), (2) Black plastic mulching (*BPM*), (3) Transparent mulching (*TM)*.

3. Elapsed time (*ETime*)

(1) 58 days, (2) 65 days, (3) 72 days, (4) 79 days, (5) 86 days.

Fruits of Summer squash harvesting started 55 days after germination.

Measurements and calculations:

1. Growth parameters

The number of leaves per plant, the number of fruits per plant were counted two times a week during the experiment. At the end of the experiment three plants were randomly selected from each treatment and the total plant weight (fresh weight), the total root length and the total length of the hair root were measured.

2. Average fruit yield per plant

Average fruit yield per plant was calculated by dividing the total fruit weights per line by the plant population count per line.

Average fruit yield per plant data were statistically analyzed using ANOVA, *L.S.D.* and *C.V.* and Duncan multiple Range Test (Little and Hills, 1978).

3. Water use efficiency

a) Marketable water use efficiency *WUE* was calculated by dividing the total marketable yield by the total irrigation amount.
b) Weakly water use efficiency *WWUE* was calculated by dividing the weekly marketable yield by the amount of irrigation water during that week.

All recorded data were statistically analyzed using "MSTATC 1990" and the least significant difference (*LSD*) test was used to compare means at the level of 5% of probability according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

1. Yield and growth parameters

Tables 2 and 3 summarize the results of the analysis of variance and the significance among the mean values of the irrigation system (*Irri)*, mulching *(Mulch) and* elapsed time *(ETime*).

The result of the ANOVA test (table 2) shows that, all three factors (*Irri*, *Mulch and ETime*) significantly affected the number of leaves per plant but there was no significant effect of the interaction between the factors on this parameter. *ETime* significantly affected the number of fruits per plant, and the fruits weight, but neither the *Irri*, nor the *Mulch* significantly affected the two parameters. The interaction between the *Irri* and the *ETime* had a significant effect on the fruit weight.

The average values of number of leaves per plant, number of fruits per plant and fruit weight are shown in table (3). From table (3) it's clear that, for all mulching treatments (No mulching (*C*), black plastic mulching (*BPM*) and transparent mulching (*TM)*) had no significant differences among them for both the average number of fruits per plant and the average fruit weight but there have been significant differences among them in the average number of leaves per plant.

For black plastic mulching (*BPM*), the average number of leaves per plant was significantly higher than the control treatment. For *ETime* treatments, almost all the averages were significantly different from each other for all the three parameters with the 72 and 79 days averages being superior to all the other averages. For *Irri* treatments, the *SSDI* had a significantly higher average number of leaves per plant than the *SDI* but the averages of both treatments were the same for both the number of fruits per plant and the fruit weight

Table 2. Analysis of variance for the No. of Leaves per plant, No. of Fruits per plant and Fruit weight, at different stages of the summer squash plants

Source of variation	df	Mean squares		
		No. of Leaves per plant	No. of Fruits per plant	Fruit weight
Irri.	1	96.00 **	1.5	3276.08
Mulch.	2	40.09*	0.33	1277.18
ETime	4	289.24***	4.72***	12143.54***
Irri. × Mulch.	2	20.54	0.14	662.93
Irri. × ETime	4	6.33	1.15	2800.84*
Mulch.× ETime	8	15.19	0.53	840.33
Irri ×Mulch.×ETime	8	17.79	0.54	350.56

df = Degrees of Freedom, *’’*** = Significant at $P < 0.05$, $P < 0.01$, and $P < 0.001$**

Table 3. Mean values of No. of Leaves per plant, No. of Fruits per plant and Fruit weight of the summer squash plants

Factor	Treatments	Mean values		
		No. of Leaves per plant	No. of Fruits per plant	Fruit weight (gm)
Mulching	C	24.28 b	2.32 a	74.24 a
	BPM	26.06 a	2.16 a	67.68 a
	TM	25.34 ab	2.22 a	64.30 a
ETime	58 days	20.63 c	20.67 d	25.1 a
	65 days	24.23 b	24.10 c	47.7 b
	72 days	25.17 b	25.67 bc	90.7 c
	79 days	28.57 a	28.87 a	64.9 d
	86 days	27.53 a	27.53 ab	42.03 b
Irri	SDI	21.62 a	20.6 a	50.8 a
	SSDI	26.51 b	22.8 a	47.1 a

Mean values within same column, followed by the same letter (a – d), are not significantly different according to LSD (*P* < 0.05).

The results of the analysis of variance and the significance among the mean values of the total plant weight and the root parameters are shown in Tables 4 and 5. The results show that only the mulch had a significant effect on the plant weight the *Irri* and the interaction between the two factors had no significant effect on the plant weight. Both the two factors and the interaction had no significant effect on the root weight, the root length and the hair root length. The comparison between the means shows that the mulching treatments had a significantly higher average plant weight than the control with no mulch. The averages of the root weight, the root length, and the hair root length were insignificant than each other for all the studied factors.

Table 4. Analysis of variance for plant weight, root weight, root length, and length of hair roots of the summer squash grown under the different treatments.

Source of variation	*df*	Mean squares			
		Plant weight	Root weight	Root length	Hair root length
Irr.	1	1326494	70.65	0.222	34.772
Mulch.	2	217152*	936.95	5.681	368.722
Irri. × Mulch.	2	665775	140.06	1.5	131.055

df = Degrees of Freedom, Irri = irrigation type, Mulch. = Mulching, * = Significant at $P < 0.05$

Table 5. Mean values of plant weight, root weight, root length, and hair root length of the summer squash grown under the different treatments.

Factor	Treatment	Mean values			
		Plant weight (gm)	Root weight (gm)	Root length (cm)	Hair root length (cm)
Mulch	C	771.65 b	30.46 a	9.17 a	37.33 a
	BPM	796.70 a	35.30 a	7.75 a	28.83 a
	TM	815.23 a	28.80 a	9.42 a	22.90 a

Mean values within same column, followed by the same letter (a – d), are not significantly different according to *LSD* ($P < 0.05$).

2. Water use efficiency

a) Marketable water use efficiency (*WUE*)

The values of the *WUE* in figure (2) show that the values of *WUE* increase with the increase of *ETime* for all treatments sharply until 68 days then the rate of increase of *WUE* with increase of *ETime* decreases. The water *WUE* for all mulch treatments were higher than the control for all recorded *ETime* for both irrigation treatments. The value of *WUE* for the control started from 0.15 kg /m^3 at 58 days *ETime* to 1.6 kg /m^3 at 83 days. For the *BPM* the values *WUE* 0.16 kg /m^3 at 58 days *ETime* to 1.81 kg /m^3 at 83 days. The values of the *WUE* started from 0.16 kg /m^3 at 58 days *ETime* to 1.85 kg /m^3 at 83 days. For the *TM* treatments. For the irrigation treatments, the values of *WUE* started from 0.154 kg /m^3 at 58 days *ETime* to 1.97 kg /m^3 at 83 days for the *SDI* treatment and the values of *WUE* started from 0.16 kg /m^3 at 58 days *ETime* to 2.01 kg /m^3 at 83 days for the *SSDI*. All the factors were insignificant in its effect but the interaction between the *ETime* and the Irrigation system significantly affected the *WUE* values.

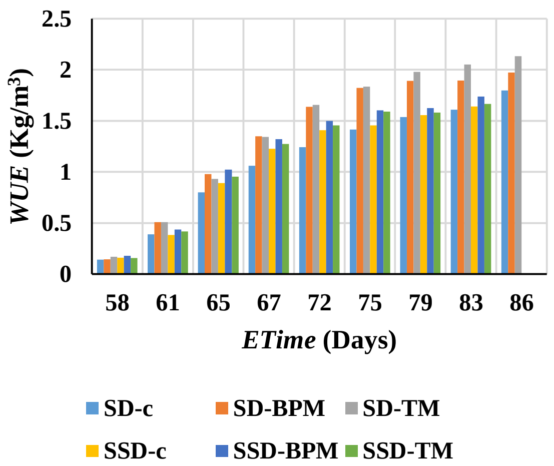

Figure 2. Marketable water use efficiency for different Elapsed time

b) Weakly water use efficiency (*WWUE*)

The values of the *WWUE* showed the same trend with all the factors insignificant and the Interaction between the *ETime* and the *Irri* significantly affecting the values of *WWUE*. The values of the *WWUE* increased with the *ETime* until 65 days for all mulch treatments under *SDI* treatment, then the values of the *WWUE* decreased sharply after that for the control and all mulch treatments under *SSDI* and gradually decreased in mulch treatments under *SDI* as shown in figure (3).

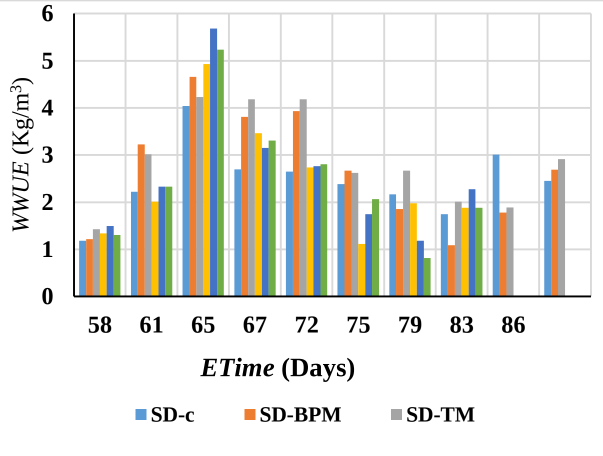

Figure 3. Weakly water use efficiency for the different Elapsed time

DISCUSSION

The results show a significant effect for all the factors on the number of leaves per plant for the *ETime*. Both the irrigation systems and the mulch effects may be due to the availability of extra water that otherwise would have been lost to evaporation that gives the plant the ability to produce more leaves per plant than the control treatment (no mulch) under surface drip system. This agrees with the results found by Anisuzzaman *et al.* (2009) who reported that black plastic mulching accelerated the growth and seed production of onion plants. These findings are similar to the results of Fan *et al.* (2012) who reported an enhancement in plant growth, fruit yield and quality of strawberries grown using different types of mulching. For the weight of fruits only the *ETime* effect and the interaction between the *ETime* and the *Irri*. were significant. Tiwari, *et al.* (2003) found that drip irrigation and mulching were effective parameters in increasing yield and *WUE* of cabbage compared to furrow irrigation. In this study. Although there was no significant difference in the total fruit, weight of all treatments but the distribution of such weight throughout the season was different from one *Irri*. treatment to the other. This explain the significance of the interaction between the *Irri*. & *ETime*. This is also evident in the *WWUE* data were the *SSDI* weekly water use efficiency values increase sharply to a maximum value higher than the values of the *SDI* weekly water use efficiency then the values decrease sharply after that to values less than the values of the *SDI* weekly water use efficiency. This can be attributed to the extra water that is available to plant in the mulched treatments and the *SSDI* treatments in the early stages of plant life where the evaporation is an important portion of the evapotranspiration, after that this effect diminishes as the transpiration becomes the dominant portion at plant maturation. The other thing is that mulching promotes early flowering and fruiting, which gives the main fruit yield in an earlier stage of plant life. This is similar to what Li, *et al.* (1999) found. They reported that the shoot of winter wheat emerged 8 days earlier in mulched treatments than treatments with no mulching. They also found the grain yield to be the greatest after 20 days of mulching and then decreased as the mulching period increased.

CONCLUSION

Both irrigation system and mulching affected the yield and the growth parameters of Squash (*Cucurbita Pepo* L.) grown in semi-arid areas. The distribution of fruit throughout the growing season was affected by the availability of more water due to the reduction of evaporation under the *SSDI* treatment and the mulching. Therefore, the maximum values of *WUE* were 2.01 kg /m^3 for the treatment with *SSDI* and *BPM* treatment, which shortened the growing season and gave most of the plant fruit production between 65 and 75 days elapsed time since transplanting *ETime*. The maximum fruit production was for the treatment with surface drip irrigation *(SDI)* and Transparent mulching *(TM).*

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تأثير نظم الري والتغطية البلاستيكية على قرع الكوسة الصيفي (.Cucurbita Pepo L) المنزرعة في المناطق شبه القاحلة

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هدفت هذه الدراسة إلى دراسة تأثير نظامين للري ونوعين من التغطية بالبلاستيك على المحصول، ومؤشرات النمو وكفاءة استخدام المياه (*WUE*) للقرع الصيفي. في هذه التجربة، استخدم نوعان من الأغطية البلاستيكية (التغطية البلاستكية السوداء *BPM* والغطاء الشفاف *TM*) بالإضافة إلى بدون تغطية (*C*)، واثنين من أنواع الري (الري بالتنقيط السطحي *SDI* والتحت السطح *SSDI*) وخمسة توقيتات من بدء الزراعة (*ETime*) 58 يومًا و65 يومًا و72 يومًا و79 يومًا و86 يومًا. كان الوزن الكلي للثمار هو نفسه تقريبا بالنسبة لجميع المعاملات، ولكن تأثر توزيع الثمار على طوال الموسم بتوافر مياه زائدة بسبب التبخر الأقل لكل من الري التحت سطحي والتغطية. الحد الأقصى لقيم *WUE* 2.01 كجم/ م^3 كان للمعاملة ذات الري التحت سطحي والتغطية بغطاء بلاستيكي اسود. هذه المعاملة تختصر موسم النمو وتنتج معظم الثمار ما بين 65 و75 يومًا من الزراعة. اقصى إنتاجية من الثمار كانت للمعاملة ذات الري السطحي والتغطية البلاستيكية الشفافة

الكلمات المفتاحية: التنقيط السطحي، بالتنقيط تحت السطحي، المهاد الأسود، المهاد الشفاف، كفاءة استخدام المياه، قرع الكوسة الصيفي.