

RESEARCH ARTICLE

Fruit Yield and Quality, and Irrigation Water Use Efficiency of Summer Squash Drip-Irrigated with Different Irrigation Quantities in a Semi-Arid Agricultural Area

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Abstract

Fruit yield, yield components, fruit mineral content, total phenolic content, antioxidant activity and irrigation water use efficiency (IWUE) of summer squash responses to different irrigation quantities were evaluated with a field study. Irrigations were done when the total evaporated water from a Class A pan was about 30 mm. Different irrigation quantities were adjusted using three different plant-pan coefficients (Kcp, 100% (Kcp1), 85% (Kcp2) and 70% (Kcp3)). Results indicated that lower irrigation quantities provided statistically lower yield and yield components. The highest seasonal fruit yield (80.0 t ha⁻¹) was determined in the Kcp1 treatment, which applied the highest volume of irrigation water (452.9 mm). The highest early fruit yield, average fruit weight and fruit diameter, length and number per plant were also determined in the Kcp1 treatment, with values of 7.25 t ha⁻¹, 264.1 g, 5.49 cm, 19.95 cm and 10.92, respectively. Although the IWUE value was the highest in the Kcp1 treatment (176.6 kg ha⁻¹ mm⁻¹), it was statistically similar to the value for Kcp3 treatment (157.1 kg ha⁻¹ mm⁻¹). Total phenolic content and antioxidant activity of fruits was higher in the Kcp1 (44.27 µg gallic acid equivalents (GAE) mg⁻¹ fresh sample) and in the Kcp2 (84.75%) treatments, respectively. Major (Na, N, P, K, Ca, Mg and S) and trace (Fe, Cu, Mn, Zn and B) mineral contents of squash fruits were the highest in the Kcp2 treatment, with the exception of P, Ca and Cu. Mineral contents and total phenolic content were significantly affected by irrigation quantities, but antioxidant activity was not affected. It can be concluded that the Kcp1 treatment was the most suitable for achieving higher yield and IWUE. However, the Kcp2 treatment will be the most suitable due to the high fruit quality and relatively high yield in water shortage conditions.

Key words: summer squash, drip irrigation, irrigation water use efficiency, total phenolic content, antioxidant activity, fruit mineral content

INTRODUCTION

Turkey is a country on the north coast of the Mediterranean region. Agriculture is the largest user of fresh water in the Mediterranean region (Katerji *et al.* 2008; Alexandridis *et al.* 2009). Turkey is also a country with limited and strategic water resources in terms of the geography of the Middle East (Bilen 2009). Therefore, an

effective irrigation schedule is important for saving water resources in this region, as this contributes to maximising profits by minimising the use of water and energy (Evans *et al.* 1996). Irrigation schedules have important roles in irrigation water use efficiency (IWUE) in vegetable crop production (Zotarelli *et al.* 2008). Knowing the water requirements of plants is the main parameter required for effective scheduling. Climatic factors (radiation, temperature, humidity and wind speed) are some of the main factors affecting water use in plants. Evaporation

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pans supply the evaporation value as an indicator of the combined effect of climatic factors on an open water surface (Savva and Frenken 2002), and the evaporation value from pans can be easily measured. As a result, pans are widely used for irrigation scheduling. Although various pan types exist, the Class A pan is the most frequently used type. A study conducted by Al-Omran *et al.* (2004) in Saudi Arabia indicated that the pan evaporation method was an acceptable method in estimating squash evapotranspiration.

Squash is considered one of the most important vegetable crops in the world due to it being a commercial crop for fields and greenhouses. 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 Turkey. The planted area of summer squash in Turkey was 10053 ha in 2011 and production was 317 705 t (TSI 2013). It is grown during spring, summer and fall seasons by using both drip and furrow irrigation methods (Amer 2011). Khalil *et al.* (1996) and Amer (2011) found that the total yield of squash was significantly higher for the drip irrigation method compared to the furrow irrigation method.

Summer squash has a shallow rooting depth and is sensitive to water in the soil. Excessive moisture or water stress may damage fruits and roots (Ertek *et al.* 2004; Amer 2011); therefore, well drained soils are suitable for summer squash. The soil water depletion fraction for the prevention of stress has to be below 0.50 (Savva and Frenken 2002).

A number of researchers have examined the effects of irrigation quantities on yield, yield components and water use efficiency (WUE). Amer (2011) showed that the fruit yield of squash grown in northern Egypt was significantly affected by irrigation quantity. Maximum yields, fruit numbers, diameters and lengths were obtained from well-watered treatments (1.0 crop evapotranspiration (ET_c)). The yield and yield component values were decreased by an excess (1.25 and 1.5 ET_c) or deficit (0.50 and 0.75 ET_c) of irrigation quantities. The highest summer squash yield was obtained from an irrigation treatment with a plant-pan coefficient of 0.85 in Van, Turkey, as reported by Ertek *et al.* (2004). Irrigation treatments with lower plant-pan coefficients (0.45 and 0.65) provided lower yields, fruit numbers, diameters and lengths. Al-Omran *et al.* (2005) indicated that the fruit yield of squash irrigated at four irrigation levels (60,

80, 100 and 120% of estimated crop evapotranspiration (ET_c)) in Riyadh, Saudi Arabia, was significantly affected by increasing irrigation quantities. Although yield was increased at higher irrigation levels (100% and 120% ET_c), it was significantly reduced at lower irrigation levels (60% and 80% ET_c). Also, water use efficiency (WUE) values were generally increased with irrigation quantity, but decreased at the highest irrigation level.

At least 49 nutrients (water, carbohydrates, protein, lipids-fat, minerals and vitamins) are required to meet the metabolic needs of humans (Welch and Graham 2004). The main source of all nutrients required for humans is agriculture (Welch 2002), and vegetables are important mineral sources for human nutrition (James and Emmanuel 2011). There are numerous functions of minerals in human biochemistry and physiology (Mayer 1997). Squash and its seeds, in terms of vitamins, protein, fat, carbohydrate and mineral substances, are important in human nutrition (Paksoy and Aydin 2004).

Epidemiological studies have shown that the consumption of fruits, vegetables and whole grains is associated with a reduced incidence of chronic diseases such as diabetes and hypertension. The health-promoting benefits of plants have been attributed to their bioactive secondary metabolites such as phenolics (Randhir *et al.* 2008). Phenolic compounds are considered beneficial for human health because they decrease the risk of degenerative diseases by the reduction of oxidative stress and the inhibition of macromolecular oxidation (Kubola and Siriamornpun 2008). Also, phenolic antioxidants play important roles in delaying the development of chronic diseases such as cardiovascular diseases, cancer, inflammatory bowel syndrome and Alzheimer's disease (Chun *et al.* 2005).

The purpose of this study was to evaluate the irrigation water use efficiency (IWUE), fruit yield, yield components, fruit mineral content, total phenolic content and antioxidant activity of summer squash for different irrigation quantities.

RESULTS AND DISCUSSION

Evaporation, precipitation and irrigation water amount

The Class A pan evaporation and precipitation values

measured in the experimental area are shown in Fig. 1. The total evaporation was 657.5 mm and total precipitation was 124.3 mm during the growing period (28 May-31 August) of summer squash. The seasonal difference between precipitation and pan evaporation values was 533.2 mm. Monthly differences between precipitation and pan evaporation values increased from the beginning of the growing period to the end of the growing period. Therefore, water production was an important input for summer squash during the growing period. The first and last irrigation dates were 3rd June and 27th August, respectively. In total, twenty irrigations were performed during the irrigation period. While the average irrigation interval was 4.3 days during the irrigation period, it was shorter than 4.3 days in last two months of the growing period due to the fact that evaporation was higher in these months (Fig. 1). Therefore, cumulative irrigation quantities for all treatments increased in a polynomial manner during the irrigation period (Fig. 2). Plant-pan coefficient (Kcp) was selected as 100% (Kcp1), 85% (Kcp2) and 70% (Kcp3) of evaporated water from a Class A pan. The highest amount of irrigation water (452.9 mm) was applied to Kcp1 treatment. The irrigation water amount applied to Kcp3 treatment was the lowest (297.1 mm) (Fig. 2). The irrigation quantities applied to the Kcp2 and Kcp3 treatments were 16.6 and 34.4% lower than the Kcp1 treatment, respectively.

Yield and yield components

The first and last harvest dates were the 9 July and 31 August, respectively; in total, 25 harvests were done during this period. The average harvesting interval was 2.1 days during the harvesting period. The first three harvests were considered the early fruit yield. Fruit yield ratios for all treatments during the harvesting period were almost constant due to the fact that the cumulative fruit yields of all treatments increased linearly during the harvesting period (Fig. 3). The yield and yield components were significantly affected by irrigation quantities (Table 1). Total fruit yield, early fruit yield, fruit number per plant, fruit diameter, fruit length and average fruit weight of summer squash were the highest for the Kcp1 treatment (Table 1). Lower

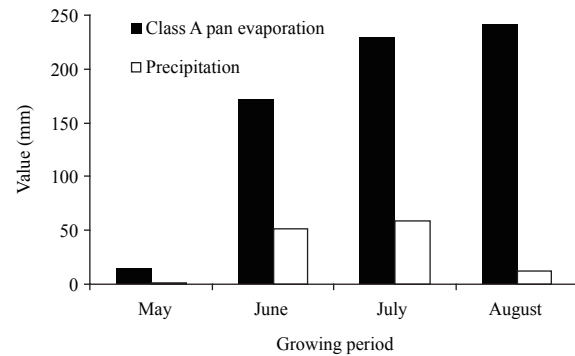


Fig. 1 Monthly Class A pan evaporation and precipitation values during growing period (28 May-31 August) of summer squash.

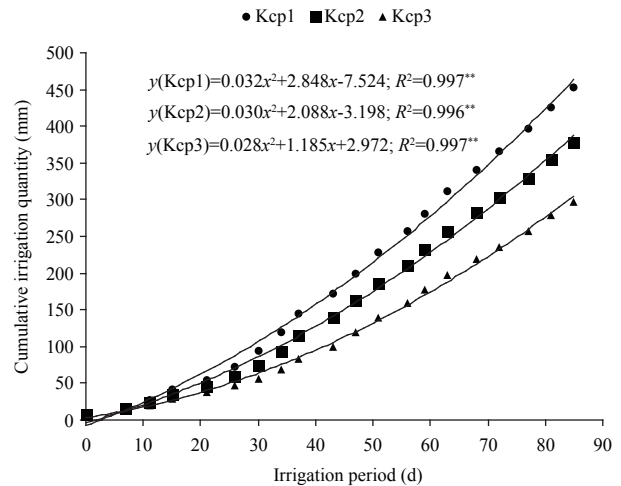


Fig. 2 The cumulative irrigation quantities applied to treatments during irrigation period (3 June-27 August) of summer squash. Plant-pan coefficient (Kcp) was selected as 100% (Kcp1), 85% (Kcp2) and 70% (Kcp3) of evaporated water from a Class A pan.

water applications caused lower yields and yield components due to plant stress in the drier soil. Total fruit yields of the Kcp2 and Kcp3 treatments were 28.5 and 41.7% lower than the value for the Kcp1 treatment, respectively. Higher fruit numbers per plant and bigger fruits provided a higher total fruit yield in the Kcp1 treatment. Early fruit yield was more affected by irrigation quantities compared to total fruit yield. The early yields of the Kcp2 and Kcp3 treatments were 39.0 and 50.8% lower than value of the Kcp1 treatment, respectively (Table 1). The fruit diameters were decreased by 9.7 and 11.1% and the fruit lengths were decreased by 2.2 and 3.8% in the Kcp2 and Kcp3 treatments when compared with the Kcp1 treatment, respectively. Therefore, it could be said that fruit di-

ameters compared to fruit lengths were more affected by water quantity. The fruit numbers per plant for the Kcp2 and Kcp3 treatments were 19.8 and 32.7% lower than value of the Kcp1, respectively. These results showed that increasing irrigation quantities on squash fruit yield and yield components had a significant positive effect. Also, a positive linear relationship was determined between irrigation quantity and total fruit yield in this study (Fig. 4). Similar results were also obtained in many other studies. Amer (2011) found that squash yield, fruit weight, number, diameter, and length were significantly decreased by the reduction of applied irrigation water according to adequately watered conditions (100% of ET_c). Ertek *et al.* (2004) concluded that irrigation quantities had significant effects on yield and yield components of summer squash and relationships between the yield and yield components with irrigation water amount were positively linear. Al-Omran *et al.* (2005) determined that squash fruit yield was higher for non-stressed irrigation conditions (100 and 120% of estimated crop evapotranspiration) compared to stressed irrigation conditions (60 and 80% of estimated crop evapotranspiration). El-Gindy *et al.* (2009) showed that a higher irrigation quantity (80% of ET_c) provided higher fresh yields, fruit diameters, fruit numbers per plant and fruit lengths in drip-irrigated summer squash compared to those with a lower irrigation quantity (60% of ET_c). El-Dewiny (2011) indicated that reducing the irrigation amount from 100 to 85% provided an increase

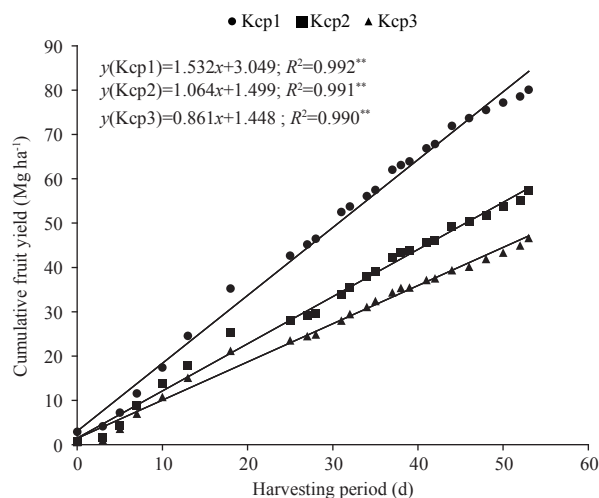


Fig. 3 The cumulative fruit yields for treatments during harvesting period (9 July-31 August) of summer squash.

Table 1 Fruit yield, yield components and irrigation water use efficiency (IWUE) of summer squash

Parameters	Treatments ¹⁾		
	Kcp1	Kcp2	Kcp3
Total fruit yield (t ha ⁻¹)	80.0 a	57.22 b	46.66 c
Early fruit yield (t ha ⁻¹)	7.25 a	4.42 ab	3.57 b
Fruit number per plant	10.92 a	8.76 b	7.35 b
Fruit diameter (cm)	5.49 a	4.96 b	4.88 b
Fruit length (cm)	19.95 a	19.52 b	19.20 b
Average fruit weight (g)	264.1 a	235.7 b	229.6 b
IWUE (kg ha ⁻¹ mm ⁻¹)	176.6 a	151.5 b	157.1 ab

¹⁾ Plant-pan coefficient (Kcp) was selected as 100% (Kcp1), 85% (Kcp2) and 70% (Kcp3) of evaporated water from a Class A pan.

Means marked with same lowercase in each row do not differ at the least 0.05%. The same as below.

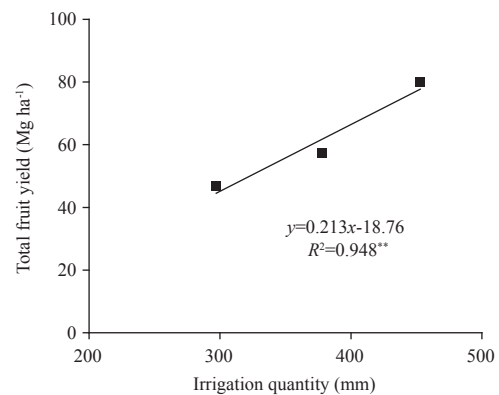


Fig. 4 Relationship between irrigation quantity and total fruit yield of summer squash.

in the yield of squash that was drip-irrigated with 100, 85, 70 and 50% of ET_c . However, increasing water deficits decreased summer squash yield.

Irrigation water use efficiency (IWUE)

The IWUE was significantly changed with irrigation quantities. The highest IWUE was found to be 176.6 kg ha⁻¹ mm⁻¹ with the Kcp1 treatment. The high IWUE value of the Kcp1 treatment can be explained by the high fruit yield of the Kcp1 treatment (Table 1). The IWUE value for the Kcp3 treatment was 157.1 kg ha⁻¹ mm⁻¹. However, there was no statistical difference between Kcp1 and Kcp3 treatments. Besides the reduction of fruit yield of squash, a higher reduction of applied water also caused an increase in the IWUE value of Kcp3 treatment. The lowest IWUE value was determined for the Kcp2 treatment as 151.5 kg ha⁻¹ mm⁻¹. The IWUE value of the Kcp2 treatment was significantly lower than the Kcp1

treatment. Generally, according to the results of different studies, lower water treatments provided higher IWUE values. Ertek *et al.* (2004) obtained the highest IWUE values for summer squash under the lowest irrigation conditions (45% of Class A pan evaporation). El-Gindy *et al.* (2009) determined that the IWUE of drip-irrigated summer squash with lower water amounts (60% of ET_0) was higher than for those irrigated with higher water amounts (80% of ET_0). El-Dewiny (2011) showed that the lowest IWUE value was obtained for full-irrigated squash and that IWUE values increased with increase water deficit. On the contrary, Al-Omran *et al.* (2005) indicated that water use efficiency was higher under higher water applied conditions (100 and 120% of ET_0) compared to lower water applied conditions (60 and 80% of ET_0).

Fruit mineral contents

Minerals in squash fruits were evaluated into two groups as major minerals (Na, N, P, K, Ca, Mg and S) and trace minerals (Fe, Cu, Mn, Zn and B). Irrigation quantities significantly affected major and trace mineral contents of summer squash fruits (Table 2). While the highest Na, N, K, Mg and S contents were determined as 0.98, 24.5, 34.5, 4.34 and 3.55 $g\ kg^{-1}$ in the Kcp2 treatment, the highest P and Ca contents were determined as 6.91 and 18.4 $g\ kg^{-1}$ in the Kcp1 treatment. All trace minerals, except Cu, were the highest for the Kcp2 treatment; Cu content was the highest for the Kcp3 treatment. These changes in the mineral contents of summer squash fruits could be explained with the available water amount in the soil. Martínez-Ballesta *et al.* (2010) reported that one of the environmental stresses affecting mineral content is drought. Also, the chemistry of the soil can be affected by the water amount in the soil. Mayer (1997) indicated that the availability to plants of minerals in the soil solution and hence crop mineral contents can vary with soil chemistry. The results on squash mineral contents of this research showed differences to the results of other studies. The fruit N, P, K and Mg contents of summer squash in this study were lower compared to the fruit mineral values of studies conducted for drip-irrigated zucchini squash by Rouphael and Colla (2005, 2009).

Table 2 Mineral contents ($g\ kg^{-1}$ dry weight) of summer squash fruits

Minerals	Treatments		
	Kcp1	Kcp2	Kcp3
Major minerals			
Na	0.92 b	0.98 a	0.82 c
N	24.2 b	24.5 a	23.6 c
P	6.91 a	6.24 b	6.85 a
K	32.2 c	34.5 a	33.1 b
Ca	18.4 a	17.8 b	17.1 c
Mg	4.23 b	4.34 a	4.08 c
S	3.23 c	3.55 a	3.42 b
Trace minerals			
Fe	0.22 c	0.29 a	0.24 b
Cu	0.024 b	0.021 b	0.033 a
Mn	0.036 b	0.040 a	0.032 c
Zn	0.123 c	0.148 a	0.141 b
B	0.013 b	0.015 a	0.012 c

However, Ca and Na contents in this study were higher according to the values of Rouphael and Colla (2005, 2009). On the contrary, the values of P, Ca, Mg, Na, Fe, Cu, Mn and Zn minerals determined in this study were higher than the values obtained in the pulp of winter squash by Valenzuela *et al.* (2011).

Total phenolic content and antioxidant activity

Total phenolic contents (TPC) of summer squash are presented in Table 3. TPC was determined in comparison with standard gallic acid and the results expressed in terms of μg gallic acid equivalents (GAE) mg^{-1} fresh sample. The total phenolic contents of summer squash were in the range of 36.60-44.27 μg GAE mg^{-1} fresh sample. The highest content of total phenolic compounds was detected in the squash extract of Kcp1 treatment, whereas the lowest content was measured in the squash extract of Kcp3 treatment. There was no statistically significant difference between the phenolic contents of treatments of Kcp1 and Kcp2. But, value of Kcp3 treatment was significantly lower than others.

For determination of the antioxidant capacity, we used the β -carotene bleaching assay. This method is commonly used for antioxidant activity determination of plant extracts (Kato *et al.* 2009). Summer squash showed a high antioxidant activity, which was lower than the reference antioxidant butylated hydroxyanisole (BHA) (98.70%), in the β -carotene bleaching assay (Table 3). The total antioxidant activity of summer squash ranged from 82.04 to 84.75%, but there were no statistically significant differences among the irrigation levels. The

Table 3 Antioxidant activities (β -carotene bleaching assay) and total phenolic content of summer squash extracts

Treatments	Total antioxidant activity (%)	Total phenolic content ($\mu\text{g GAE mg}^{-1}$ fresh sample) ²⁾
Kcp1	82.04	44.27 a
Kcp2	84.75	43.94 a
Kcp3	82.78	36.60 b
BHA ¹⁾	98.70	-

¹⁾ BHA, butylated hydroxyanisole.²⁾ GAE, gallic acid equivalent.

antioxidant effect is mainly due to phenolic compounds (flavonoids, phenolic acids, and phenolic diterpenes) (Javanmardi *et al.* 2003).

CONCLUSION

In this study, different irrigation quantities calculated according to 100% (Kcp1), 85% (Kcp2) and 70% (Kcp3) of evaporated water from a Class A pan were investigated on summer squash. The applied seasonal water amounts, the total fruit yield and early fruit yield in the Kcp1 treatment were significantly higher than the others. Also, fruit diameter, length, and number per plant, and the average fruit weight were the highest in the Kcp1 treatment, and the lower yield and yield components in the Kcp3 treatment were determined due to squash being a sensitive vegetable to water stress in soil. The IWUE was affected for both yield and irrigation quantity. Therefore, despite the Kcp1 treatment providing a higher IWUE value, this was not statistically different from the IWUE value of treatment Kcp3.

The mineral intake of plants from the soil solution was affected by irrigation quantities. Fruit Na, N, K, Mg, S, Fe, Mn, Zn and B contents were the highest in the Kcp2 treatment. Furthermore, P and Ca contents in the Kcp1 treatment and Cu content in the Kcp3 treatment were the highest. The highest total phenolic content and antioxidant activity was obtained in the Kcp1 and Kcp2 treatments, respectively. However, there were no statistically significant differences between irrigation treatments for total phenolic content and antioxidant activity.

From the results of this study, Kcp1 treatment had the highest yield and IWUE. Therefore, 100% Kcp was recommended for summer squash grown in field conditions, even though 85% Kcp may be suitable for better quality summer squash, especially in regions of water deficit.

MATERIALS AND METHODS

Experimental site, soil and weather properties

The study was conducted in 2010 at the Agricultural Research Station of Ataturk University, Erzurum, Turkey (39°43'N and 41°14'E, 1 793 m a.s.l.). The experimental region has a semi-arid climate. During the growing season (28 May-31 August), the mean temperature, relative humidity, wind speed, daily sunshine, total evaporation and total precipitation were 18.3°C, 54.1%, 3.3 m s⁻¹, 9.7 h, 657.5 mm and 124.3 mm, respectively. While precipitation and evaporation data were measured with a standard pluviometer and a Class A pan, respectively, which were placed in the experimental area, others were collected at the Erzurum weather station which located 2.5 km far from the experimental site.

The soil of the experimental region is Aridisol, according to the US Soil Taxonomy (Soil Survey Staff 1992), and the experimental field soil is medium textured. Some physical and chemical soil properties determined according to the methods by Klute (1986) and Page *et al.* (1982) are given in Table 4. The amount of available water for a soil depth of 60 cm is 87.6 mm in the experimental area.

Table 4 Some physical and chemical properties of experimental field soil

Properties	Soil depth (cm)	
	0-30	30-60
Texture	Clay loam	Loam
Clay (%)	29.8	25.7
Silt (%)	35.3	34.2
Sand (%)	34.9	40.1
Bulk density (g cm ⁻³)	1.34	1.38
Field capacity (P _w)	30.1	27.4
Wilting point (P _w)	18.7	17.3
pH	7.64	7.43
Electrical conductivity (dS m ⁻¹)	1.35	1.63
Carbonates (%)	2.24	1.98
Organic C (g kg ⁻¹)	1.68	1.05

Experimental design and applications

The experiment was conducted with three replicates. Experimental plots were arranged as 8.4 m long and 2.4 m wide. Plots were surrounded by a 1.5 m dry area to prevent the passage of water from adjacent plots. Summer squash (*Cucurbita pepo* L.) hybrid Eskenderany variety seedlings were planted in 4 rows in each plot on 28 May. The planting distances were 60 cm×60 cm, both between and within rows, and there were 56 plants in each plot. Before planting, during the soil preparation, manure was applied over the whole area at a rate of 30 t ha⁻¹. No pesticide was applied during the growing period, and required hoeing was done by hand.

Groundwater that stored in a pool was used as irrigation

water. The pH value of the water was 7.35 and there was no salinity or sodium risk. Irrigation water was applied using a drip irrigation system consisting of a control unit and distribution lines. The required operation pressure was provided by a centrifuge pump. The control unit had a screen filter, a flow meter, a pressure gauge and valves. Polyethylene (PE) manifolds of 50 mm in diameter were placed along the edge of each plot, and the PE driplines (linear low density polyethylene round pipe, with two outlets and the manufacturing coefficient variation (CV)<3%) had in-line type round emitters with a distance of 0.60 m and a diameter of 16 mm. The flow rate of each emitter was 4 L h⁻¹ under an operating pressure of 0.1 MPa. Driplines were placed near each crop row in the experimental plots, resulting in 4 driplines on each plot. Irrigation water was applied to the plots according to the calculated irrigation times; irrigations were manually controlled with valves on the manifolds.

Irrigation scheduling was based on Class A pan evaporation. Irrigations were performed when the total amount of evaporated water from the Class A pan located near the experiment field was about 30 mm. The evaporation values from the Class A pan were measured with a manual ruler that had an accuracy of 1 mm in a stilling well that is situated in the pan near one edge. For the calculation of the required irrigation water amount, the below pan evapotranspiration equation (eq.) 1 was used (Ertek 2011):

$$I = E_{pan} \times K_{cp} \times P \quad (1)$$

Where, I is the amount of required irrigation water (mm), E_{pan} is the total evaporation amount (mm), K_{cp} is the plant-pan coefficient, and P is the wetting factor. Three different plant-pan coefficients (K_{cp1}: 100%; K_{cp2}: 85% and K_{cp3}: 70%) were selected (Ertek *et al.* 2004). The wetting factor (P) according to growth rates was determined by the eq. 2 (Ertek 2011):

$$P = (W_p / W_b) \quad (2)$$

Where, W_p is the plant cover width (m), and W_b is the plant row interval (m).

Mean plant cover width was measured before irrigation application for every K_{cp} treatment. The P values were shown in Fig. 5.

Harvests from the two centre rows in each plot were done by hand. Marketable immature fruits were counted and weighted in each harvest. Fruit diameters and lengths were measured. Also, the mineral content, total phenolics and antioxidant activities of squash fruits were analysed for yield quality.

Analyses

For mineral analysis, squash fruit samples were washed with distilled water, then dried in an oven for 48 h at 68°C and powdered. Major minerals (Na, P, K, Ca, Mg and S) and trace minerals (Fe, Cu, Mn, Zn and B) were found after wet digestion using a HNO₃-H₂O₂ acid mixture (2:3 v/v) with three different steps (first step: 145°C, 75% radio-frequency (RF), 5 min;

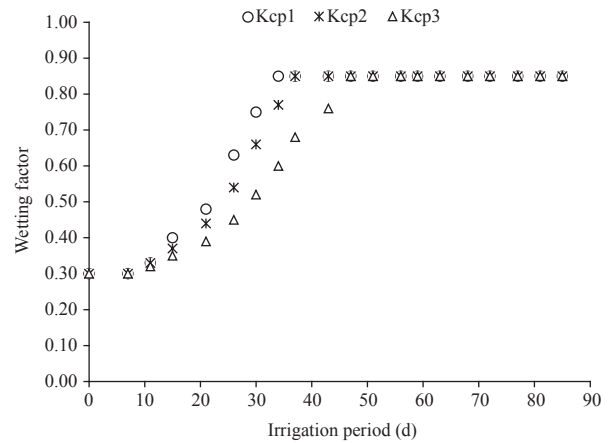


Fig. 5 The wetting factor (P) for each K_{cp} during the growing season.

second step: 180°C, 90% RF, 10 min and third step: 100°C, 40% RF, 10 min) in a microwave unit (Berghof, Germany) (Mertens 2005a). Major and trace minerals were determined by using an ICP OES spectrophotometer (Perkin-Elmer, USA) (Mertens 2005b). Total nitrogen content was determined by the Micro-Kjeldahl method (Bremner and Mulvaney 1982).

For phenolic and antioxidant analysis, 10 g of the squash pulp was mixed with 10 mL ethanol and stirred for 6 h on a magnetic stirrer. The suspension was filtered through Whatman No. 1 filter paper (Sengul *et al.* 2011). Final solutions were used as stock solutions for the analysis of antioxidant activity and phenolic compounds and kept at -20°C until analysis.

Total phenolics content in the ethanol extracts of squash was determined by the Folin-Ciocalteu colorimetric method (Gulcin *et al.* 2002) with analytical grade gallic acid as a standard. Briefly, 1 mL of the solution (containing 1 mg of sample) extract in water was pipetted into a flask. Then, 46 mL of distilled water and 1 mL of Folin and Ciocalteu's reagent was added and mixed thoroughly. The mixture was left to stand for 3 min and 3 mL of 2% sodium carbonate was added. After 120 min incubation at ambient temperature with shaking, the resulting absorbance was measured at 760 nm. Measurements were carried out in triplicate, the calibration curve was performed with gallic acid, and the results were expressed as µg of gallic acid equivalents (GAE) per mg of sample (µg GAE mg⁻¹ sample) (Sengul *et al.* 2011).

The antioxidant activity in the ethanol extracts of squash was determined according to the β-carotene bleaching method described by Kaur and Kapoor (2002) with some modifications. Briefly, 4 mL of β-carotene solution (0.1 mg in 1 mL chloroform), 40 mg of linoleic acid and 400 mg of Tween 40 was transferred to a round-bottom flask. The mixture was then evaporated at 50°C by means of a rotary evaporator to remove the chloroform. Then, 100 mL of oxygenated distilled water was added slowly to the residue and vigorously agitated to give a stable emulsion. Then, 800 µL of the extracts was added to 3 mL aliquots of β-carotene/linoleic acid emulsion. As soon as the emulsion was added to each tube, the zero time absorbance

was measured at 470 nm using a spectrophotometer. The mixtures were then incubated at 50°C for 100 min, and the measurements were carried out at 10 min intervals for a total of 100 min. Water was used instead of plant extract as a control. A blank, devoid of β -carotene, was prepared for background subtraction. Butylated hydroxyanisole (BHA) was used as a standard. All samples were assayed in triplicate. The degradation rate (DR) was calculated according to first order kinetics, using eq. 3 (Sengul *et al.* 2011):

$$\ln(a/b) \times 1/t = DR_{\text{sample}} \text{ or } DR_{\text{standard}} \quad (3)$$

Where, a is the initial absorbance (470 nm) at time 0, b is the absorbance (470 nm) at 100 min and t is time.

Antioxidant activity (AA) was expressed as percentage inhibition relative to the control, using eq. 4 (Sengul *et al.* 2011):

$$AA = (DR_{\text{control}} - DR_{\text{sample}} \text{ or } DR_{\text{standard}} / DR_{\text{control}}) \times 100 \quad (4)$$

Irrigation water use efficiency (IWUE) was calculated by dividing the economic yield (kg ha⁻¹) by the amount of seasonal irrigation water (mm) (Howell 2001). However, total marketable yield was used instead of economic yield in our study.

Analysis of variance (ANOVA) was performed to evaluate the effects of different irrigation water treatments on IWUE, fruit yield, yield components and fruit quality. Duncan's multiple range test was used to compare and rank the treatment means.

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