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Effects of different irrigation programs on the growth, yield, and fruit quality of drip-irrigated melon

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Abstract: A field study was conducted in Ankara, a semi-arid region of Central Anatolia, Turkey, on clay-loamy soils in the vegetation seasons of 2005 and 2006. Kırkağaç melon cultivar (*Cucumis melo* L. cv. Kırkağaç) was irrigated by the drip method from transplantation to the beginning of the flowering (IS_f), fruit setting (IS_{fs}), ripening (IS_r), and harvesting (IS_h) periods. Water amounting to 50% (P_{50}), 75% (P_{75}), and 100% (P_{100}) of full irrigation water were applied. Some analyses were carried out regarding the growth, yield, and fruit quality parameters in these irrigation programs. Moreover, the amount of water, the seasonal evapotranspiration, and the water use efficiency having been used were determined for each irrigation program. Carrying on the irrigation during the ripening period furthered shoot growth except P_{100} application, did not significantly affect fruit yield and the soluble solids content of the fruit flesh. Similar but relatively larger fruit size and heavier weight were found in the treatments of IS_r and IS_h. Fruit yields in the P_{75} and P_{100} applications were found similar, but they were found to be higher than the P_{50} application. The soluble solids contents and the ratings of sensory characteristics were higher in the P_{75} application. As a result of this study, with respect to the considerably high yield and fruit quality, it was suggested that irrigation be kept on going until the beginning of fruit setting, not during the ripening period, and the application of 75% of full irrigation water amount (IS_r P_{75}) is the most convenient irrigation program. In addition, irrigation water amounting to 319.6-331.1 mm was applied and 427.1-472.6 mm seasonal evapotranspiration and 8.9-9.2 kg m^{-3} water use efficiency was determined in the (IS_r P_{75}) irrigation program.

Key words: Kırkağaç, melon, drip irrigation, yield, fruit quality, water use efficiency

Damla yöntemiyle sulanan kırkağaç kavununda farklı sulama programlarının gelişme, verim ve meyve kalitesine etkileri

Özet: Çalışma, Orta Anadolu'nun yarı kurak iklim bölgesinde yer alan Ankara ilinde, killi tın topraklarda, 2005 ve 2006 yıllarında yürütülmüştür. Damla yöntemiyle sulanan Kırkağaç kavun çeşidi (*Cucumis melo* L. cv. Kırkağaç), dikimden başlayarak, çiçeklenme (IS_f), meyve oluşumu (IS_{fs}), olgunlaşma (IS_r) ve hasat (IS_h) başlangıcına kadar sulanmış, bitkilere tam sulama konusunun % 50 (P_{50}), % 75 (P_{75}) ve % 100'ü (P_{100}) kadar su verilmiştir. Bu sulama programlarında, bazı bitki gelişmesi, verim ve meyve kalitesi parametrelerine ilişkin ölçme ve analizler yapılmıştır. Her sulama programı için uygulanan sulama suyu miktarları, mevsimlik toplam su tüketimleri ve su kullanım randımanları saptanmıştır. Sulamaya olgunlaşma periyodunda devam edilmesi, P_{100} uygulamaları dışında, vejetatif gelişmeyi arttırmış, verimi ve kuru maddeyi önemli düzeyde etkilememiştir. IS_r ve IS_h deneme konularında benzer ancak diğerlerinden yüksek meyve

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büyüklüğü ve ağırlığı bulunmuştur. Meyve verimi P_{75} ve P_{100} uygulamalarında benzer ancak P_{50} uygulamasından yüksek olmuştur. P_{75} uygulamasında, diğer P uygulamalarından daha yüksek kuru madde ve tat özellikleri elde edilmiştir. Araştırma sonucunda, yüksek verim ve kalite açısından, sulamaların olgunlaşma başlangıcına kadar sürdürülmesinin ve olgunlaşma periyodunda sulama yapılmamasının, bunu yanında, tam sulama suyu miktarının % 75'i kadar su verilmesinin (IS_rP_{75}) en uygun sulama programı olduğu bulunmuştur. IS_rP_{75} sulama programında, 316.9-331.1 mm sulama suyu uygulanmış, bitki su tüketimi 427.1-472.6 mm, su kullanım randımanı 8.9-9.2 kg m^{-3} olarak saptanmıştır.

Anahtar sözcükler: Kırkağaç, kavun, damla sulama, verim, meyve kalitesi, su kullanım randımanı

Introduction

The largest melon producers in the world are China, Turkey, Iran, and United States, accounting for 57% of the global production. Melon production in Turkey represents about 9% of the total vegetable production (SIS, 2003).

Kırkağaç is one of the commonly grown melon cultivars, particularly in the Aegean and the Central Anatolia regions of Turkey. Its fruit flesh is sweet and delicious and they are more resistant to transportation and postharvest resting than many other cultivars. The average fruit weight, the fruit size and the soluble solids contents of the fruit flesh are 2.4 kg, 15.5 cm and 9 % (Sivritepe et al., 1999).

Melon is moderately sensitive to soil salinity and to the lack of soil water (Kuşvuran et al., 2007). The most sensitive periods for soil water deficit are the fruit setting and flowering (Fabeiro et al., 2002). Soil water deficit during the ripening period does not significantly affect fruit yield and generally increases or does not change the fruit quality, particularly the soluble solids, which are primarily the sugar content of the fruit flesh (Warriner and Henderson, 1989; Shishido et al., 1992; Hartz, 1997; Matheis and Fellman, 1999; Gil et al., 2000; Faberio et al., 2002). Irrigation close to harvest causes a reduction in the soluble solids (Bhella, 1985; Lester et al., 1994). Application of saline water lowers the yield but results in an increase in the soluble solids in general (Medlinger and Fossen, 1993; Meiri et al., 1995; Amor et al., 1998).

Melon is commonly irrigated by furrow or drip irrigation methods. In soils with a considerably high water holding capacity and under full irrigation, similar yields could be obtained through both methods, but irrigation water requirements fall and water use efficiency rises up by using drip irrigation (Bogle and Hartz, 1986; Warriner and Henderson, 1989). Frequent irrigation causes cracks in fruit, and very rare irrigation limits root and shoot development and also the fruit size and the yield (Flocker et al., 1965; Pew and Gardner, 1983). Applying of drip irrigation increases the fruit size and the marketable yield and may also bring about early harvest in sandy soils (Shmueli and Goldberg, 1971; Bhella, 1985; Warriner and Henderson, 1989; Coelho et al., 1999; Sousa et al., 1999; Leskovar et al., 2001).

Application of limited amounts of water may improve fruit quality and sometimes improve the yield compared with the use of full irrigation (Hernandez et al., 1995; Alizadeh et al., 1999; Gil et al., 2000; Lei et al., 2003). Yields could significantly decrease by using less amount of water than recommended for some cultivars (Dasgan et al., 1999; Ribas et al., 2001). An excessive water deficit could reduce the fruit count per plant, fruit size, and yield, but increases the soluble solids content in general (Shishido et al., 1992; Hernandez et al., 1995).

The studies on the effects of the irrigation programs on melon growth and yield indicate that selection of a particular cultivar could dictate the specific irrigation program and water requirements in addition to the usual factors such as climate, soil, topography, and water resource. However, little is known on this subject with respect to Kırkağaç melon. For this reason, a study was undertaken to determine the appropriate irrigation program and water requirements for drip-irrigated Kırkağaç melon grown in a semi-arid region and in soils with high water holding capacity.

Material and methods

Experimental site: This study was carried out in an experimental field in the Horticultural Research Station of Agricultural Faculty, University of Ankara, Turkey, (40°01´ N, 32°20´ E, 825 m above mean sea level) in the vegetation seasons of 2005 and 2006. The experiments were set up in different halves of the same field in both years.

The station was situated in a semi-arid climatic region. Long term annual total precipitation was 396.2 mm and the mean temperature was 13.0 °C (100.0 mm and 22.0 °C for the vegetation season of melon, along May to August). In the vegetation seasons, these values were actually 95.6 mm and 22.9 °C in 2005 and 61.9 mm and 23.7 °C in 2006, respectively.

In each experimental year, soil samples were collected from 0-30 cm, 30-60 cm, 60-90 cm, and 90-120 cm soil layers of the two profiles before the start of the experiments. Texture class, electrical conductivity, lime content, pH, and available water holding capacity were found to be clay-loam, 0.4-1.6 dS m^{-1}, 12-16%, 8.1-8.2, and 147.0 mm m^{-1}, respectively, by analyzing these soil samples. In addition, soils at the experimental site were also determined to be deep and quite homogeneous from the viewpoints of the soil texture and topography.

The average intake rate of soil was determined as 5.4 mm h^{-1} using double ring inflitrometers.

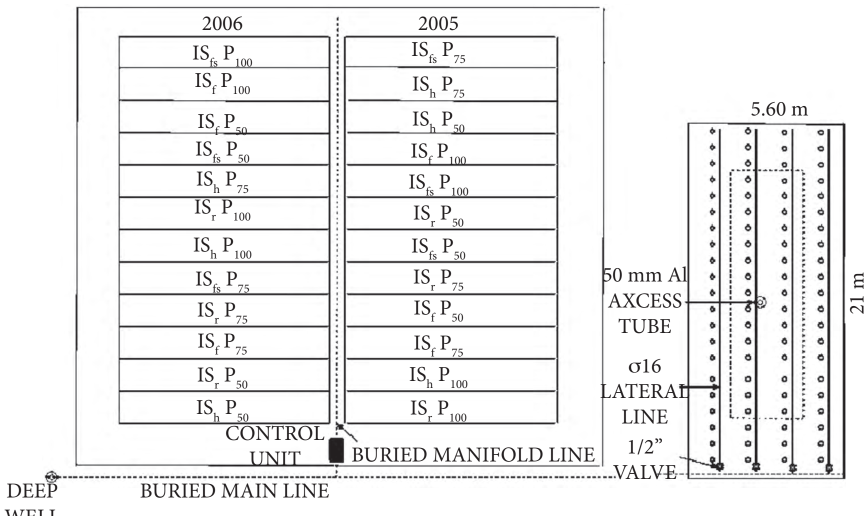
Water resource was a deep well and electrical conductivity of irrigation water was determined as 1.9 dS m^{-1}.

Treatments and experimental design: Kırkağaç melon (*Cucumis melo* L. cv. Kırkağaç) was irrigated by the drip method from transplantation to the beginning of the flowering (IS_f), fruit setting (IS_{fs}), ripening (IS_r), and harvesting (IS_h) periods, additionally, water amounting to 50% (P_{50}), 75% (P_{75}), and 100% (P_{100}) of full irrigation water amount was applied in order to get different irrigation programs.

Because the soil texture and topography were homogeneous, the experimental design was a randomized parcel design with two factors such as the irrigation season (IS) and the percentage of full irrigation (P). Thus, experimental site included 12 parcels in both years. Each parcel included 4 plant row and 21 plants in each row. Plantation intervals were chosen as 1.40 × 1.00 m (Sarı et al., 2000). Observations and measurements were carried out on 30 plants in two rows in the middle (Figure 1).

The Ø16 PE lateral drip lines were set about 25 cm close to each plant row. Drip lines consisted of inline drippers with 4 L h^{-1} discharge rate at 1 b operational pressure and spaced at 0.75 m in order to obtain a continuous wet strip along plant row. These lateral layout and dripper characteristics were chosen by taking plant row space (1.40 m) and soil intake rate (5.4 mm h^{-1}) into consideration (Papazafiriou, 1980).

In the first year, the percentage of the wetted area was determined by digging soil with shovel and



a) Layout of experim ents b) Detail of a parcel

Figure 1. Experimental design

measuring the shape of the soil surface at depth of 20-30 cm at 18 locations one day after the first and the second irrigations (Merriam and Keller, 1978). The mean percentage of the wetted area was obtained as 64.3%.

Melon seedlings were grown in a greenhouse and transplanted to the experimental plots in May (May 24th 2005 and May 17th 2006). Irrigation water was applied to all plots during transplantation in order to bring existing soil moisture in the field capacity to a 90 cm soil depth (15.4 mm in 2005 and 34.7 mm in 2006).

Soil moisture measurements: The volumetric soil moisture content was measured daily in each 30 cm layer of the 120 cm soil depth using a neutron-probe (CPN, 503 DR Hydroprobe) calibrated for the soil characteristics of the experimental site. For this purpose, 2” aluminum access tubes were installed in the middle of each plot about 25 cm in proximity to a randomly chosen dripper. The moisture contents of 90 cm and 120 cm soil depth were used for determination of water amount applied in each irrigation and seasonal evapotranspiration, respectively.

Irrigation: In the experimental plots where full irrigation water amounts was applied (P_{100}) irrigation was initiated when 30-40% of water holding capacity was consumed (Faberio et al., 2002) in a 90 cm soil depth to bring the measured soil moisture content in field capacity. Full irrigation water amount was calculated using the equation giving below;

$$d = \frac{FC_{0-30} - M_{0-30} + FC_{30-60} - M_{30-60} + FC_{60-90} - M_{60-90}}{100} DP$$

where d = full irrigation water amount (mm), FC_{0-30}, FC_{30-60}, FC_{60-90} = field capacity at the soil layers of 0-30 cm, 30-60 cm, and 60-90 cm (% vol.), M_{0-30}, M_{30-60}, M_{60-90} = soil moisture was measured at the beginning of the irrigation at the mentioned soil layers (% vol.), D = depth of soil layer (300 mm), and P = the ratio of wetted the soil surface (0.643).

Irrigation water amounting to 25.5 mm and 34.0 mm was applied in each irrigation for the P_{100} application. Irrigation water of 50% (P_{50}) or 75% (P_{75}) of full irrigation water amount was applied to the other experimental plots.

Seasonal evapotranspiration: Seasonal evapotranspiration was determined according to the soil moisture balance. For this purpose, the amount of the irrigation water and the effective rainfall were added to the soil moisture difference measured during transplantation and in the previous harvest (Jensen et al., 1989). Soil moisture values measured at the 120 cm soil depth were considered for evapotranspiration to determine probable deep percolation. Rainfall levels were considered to be effective because individual rainfall occurring during vegetation seasons in the experimental years was less than 25 mm. In addition, surface runoff was not observed.

Cultivation, plant protection, and fertilization: Standard farming practices were applied for cultivation and plant protection at the experimental site. Fertilizer type and amount were determined founding on the results of the soil productivity analysis, which were carried out for both experimental years; fertilizer amounts of 340 kg ha^{-1} 19-19-19, 80 kg ha^{-1} 11-44-11, and 80 kg ha^{-1} 16-6-31 in 2005 and 400 kg ha^{-1} 19-19-19, 100 kg ha^{-1} 11-44-11, and 60 kg ha^{-1} 16-6-31 were applied by admixing with irrigation water.

Growth, yield, and fruit quality measurements: Female flowers per plant were counted during the flowering period on ten plants chosen randomly from 30 observed plants in each experimental plot. Shoot number per plant and shoot length were determined using the same 10 plants during a week stage before harvest.

In each experimental plot, the count of marketable fruit per plant was determined and the weight of each fruit was obtained from 30 observed plants. Total weight of fruit for each plant was considered to be fruit yield per plant. In addition, the width and length of the whole fruits of a plant were determined and the average of these two values was taken as the fruit size.

Six fruits were randomly chosen from the whole of harvested fruits in a plot and then these selected fruits were cut into slices. Ten experts graded sensory characteristics of fruits and rated numerically as 5 (excellent), 4 (good), 3 (moderate), 2 (bad), and 1 (very bad) by taking odor, taste, aroma, color, brightness, and hardness of the fruit flesh into consideration. The remaining flesh of the six selected fruits was blended and the resulting juice was filtered. The total soluble solids content in the juice was determined by a refractometer and expressed as a percentage. Acidity was determined by potentiometric titration with 0.1 N NaOH to pH 8.1, using 50 mL of juice and with the results expressed as the percentage of the citric acid in juice (Mitcham et al., 1996). These analyses were carried out with 3 replications.

Water use efficiency: Water use efficiency for each treatment was determined in units of kg m^{-3} using fruit yield and seasonal evapotranspiration values (Howell et al., 1990).

Statistical analysis: All the data on the growth, yield, and fruit quality were analyzed statistically by ANOVA, using MINITAB statistical software according to factorial design in randomized parcels repeated in years. Replications were 10 for shoot number per plant, shoot length, and female flower count per plant, 30 for fruit number per plant, fruit size, fruit weight, and yield per plant, and 3 for total soluble solids and titratable acidity (Winer et al., 1991). Means were declared to be significantly different at the 0.05 level using Duncan's multiple range test. Because the data for the sensory characteristics were the ratings of experts, they were not subjected to parametric testing.

Results

Applied irrigation water and evapotranspiration: The amount of the seasonal irrigation water applied and evapotranspiration results are shown in Table 1. Irrigation water amounting to 85.7 mm and 551.9 mm was applied to

Table 1. Results of the seasonal irrigation water amount and evapotranspiration (ET, mm)

Year	Irrigation season	Percentage of full irrigation	Irrigation water applied (mm)	Rainfall (mm)	Soil moisture difference (mm)	Evapotranspiration (mm)
	IS_f	P_{50}	110.1		+105.9	311.6
		P_{75}	165.1		+87.7	348.4
		P_{100}	220.1		+84.0	399.7
	IS_{fs}	P_{50}	162.8		+101.2	359.6
		P_{75}	244.2		+85.8	425.6
2005		P_{100}	325.6	95.6	+84.0	505.2
	IS_r	P_{50}	211.3		+13.7	320.6
		P_{75}	316.9		+14.6	427.1
		P_{100}	422.5		-1.3	516.8
	IS_h	P_{50}	230.3		-8.4	317.5
		P_{75}	345.4		-16.2	424.8
		P_{100}	460.5		-30.7	525.4
	IS_f	P_{50}	85.7		+143.9	291.5
		P_{75}	128.6		+145.7	336.2
		P_{100}	171.4		+131.3	364.6
	IS_{fs}	P_{50}	134.7		+117.2	313.8
		P_{75}	202.1		+97.5	361.5
2006		P_{100}	269.4	61.9	+95.3	426.6
	IS_r	P_{50}	220.7		+91.4	374.0
		P_{75}	331.1		+79.6	472.6
		P_{100}	441.4		+83.8	587.1
	IS_h	P_{50}	276.0		+4.0	341.9
		P_{75}	413.9		+11.1	486.9
		P_{100}	551.9		-9.1	604.7

the experimental plots. Evapotranspiration values ranged from 291.5 mm to 604.7 mm in the vegetation seasons of the experimental years. Seasonal irrigation water amount and evapotranspiration naturally increased when irrigation season (IS) was long and the amount of irrigation water applied in each irrigation (P) was high.

Growth components: The results of shoot number per plant, shoot length, and female flower number per plant are shown in Table 2 and 3 with the statistical analysis.

The mean shoot number ranged from 4.7 to 5.3 per plant (5.0 as a general average). Experimental years (Y), irrigation season (IS) and the percentage of full irrigation (P) did not significantly affect shoot number. Thus, shoot number was a cultivar characteristic and did not depend on the irrigation programs used.

The mean shoot length per plant ranged from 101 to 199 cm. The IS treatments did not significantly affect shoot length, but shoot length did significantly vary between years (Y) and the P applications. In

Table 2. Results of shoot number per plant and shoot length

Irrigation season (IS)	Year (Y) 2005, Percentage of full irrigation (P): P_{50}	P_{75}	P_{100}		Year (Y) 2006, Percentage of full irrigation (P): P_{50}	P_{75}	P_{100}		General average
(1) Shoot number per plant									
IS_f	4.9	4.9	5.1		5.0	4.8	4.7		
IS_{fs}	5.0	5.0	4.9		5.3	4.7	4.8		
IS_r	5.0	4.8	5.0		5.2	4.9	5.0		
IS_h	5.2	4.9	4.9		4.8	5.1	4.8		5.0
Y^{ns} [z] IS^{ns} P^{ns} $Y \times IS^{ns}$ $Y \times P^{ns}$ $IS \times P^{ns}$ $Y \times IS \times P^{ns}$									
(2) Shoot length (cm)				Average				Average	
IS_f	129	163	169		104	145	147		
IS_{fs}	154	163	171		101	124	171		
IS_r	141	138	199		114	124	187		
IS_h	143	163	172		151	144	164		
Average				159 A [y]				140 B	
Y^{***} [z] IS^{ns} P^{***} $Y \times IS^{ns}$ $Y \times P^{ns}$ $IS \times P^{*}$ $Y \times IS \times P^{ns}$									

Interactions of ISxP

	P_{50}	P_{75}	P_{100}
IS_f	117 c **c** [x]	154 a **b**	158 d **a**
IS_{fs}	128 b **c**	144 b **b**	171 b **a**
IS_r	128 b **c**	131 c **b**	193 a **a**
IS_h	147 a **c**	154 a **b**	168 c **a**

[y] : Capital letters indicate significantly differences among Y.
[x] : Small and bold small letters indicate significantly differences among IS in each P and among P in each IS, respectively.
[z] : ns, *,**,*** non-significant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

Table 3. Results of female flower number per plant

Irrigation season (IS)	Year (Y)					
	2005			2006		
	Percentage of full irrigation (P)					
	P_{50}	P_{75}	P_{100}	P_{50}	P_{75}	P_{100}
IS_f	12.4	10.1	8.1	4.9	8.8	5.2
IS_{fs}	10.5	6.7	9.0	8.0	8.2	7.2
IS_r	11.8	9.6	9.3	7.7	7.4	7.6
IS_h	10.8	9.2	8.2	6.8	8.5	7.0

Y *** (z) IS ns P * Y × IS ns Y × P ns IS × P ns Y × IS × P ns

		2005	2006	Average
	P_{50}	11.4	6.9	9.2 **a** (y)
	P_{75}	8.9	8.2	8.6 **ab**
	P_{100}	8.7	6.8	7.8 **a**
Average		9.7 A (y)	7.3 B	

(y): Bold small and capital letters indicate significantly differences among P and among Y, respectively.
(z): ns, *,**,*** non-significant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

addition, the ISxP interaction was found to be significant. In general, longer shoots were measured in the first experimental year (159 cm). The longest shoots were formed in the IS_h treatment for P_{50} (147 cm), in the IS_f and IS_h treatments for P_{75} (154 cm), and in the IS_r treatment for P_{100} (193 cm) applications. Shoot length increased by increasing the amount of water applied in each irrigation (from P_{50} to P_{100}) in the whole of the IS treatments. On the other hand, a regular increment of shoot length was not found with increasing of irrigation season duration, particularly in the P_{75} and P_{100} applications. Shoots grew more with continuing irrigation during ripening period in the P_{50} and P_{75}, but shorter shoots were formed in the IS_h treatment for the P_{100} application.

The mean female flower count ranged from 4.9 to 11.8 per plant. Years (Y) and the P applications significantly affected female flower number with the exception of the IS treatments. In general, higher female flower counts were seen in the first year (9.7). Female flower counts were decreased with increasing irrigation water amount applied in each irrigation. This result should evaluate that a negative relation exists between vegetative growth and female flower count per plant.

Yield components: The results of fruit number per plant, fruit size, fruit weight, and fruit yield per plant are shown in Table 4 and 5 including statistical analysis.

The mean fruit number ranged from 1.6 to 3.0 per plant. The treatment of irrigation seasons (IS) and the percentages of full irrigation (P) did not significantly affect fruit number. Fruit number variations as dependent upon the experimental years (Y) were significant, and more fruits developed on plants in the first year (2.8 as an average).

The experimental years (Y), the IS treatments and the P applications significantly accounted for variations in fruit size varying between 13.7 cm and 22.0 cm. In addition, the YxISxP interactions were found significant. In general, bigger fruits were harvested in the second year. This result could be related to lower fruit number per plant in this year. Increments in the fruit size were evident in the treatments of IS_r and IS_h compared with the other treatments. Fruit sizes obtained in the treatments of IS_r and IS_h were found to be relatively similar. Furthermore, in the treatments of irrigation season except IS_h, bigger fruits were generally obtained in the P_{75} and P_{100} applications, and fruit size was also similar

Table 4. Results of fruit number per plant and fruit size

Irrigation season (IS)	Year (Y)							
	2005				2006			
	Percentage of full irrigation (P)							
	P_{50}	P_{75}	P_{100}		P_{50}	P_{75}	P_{100}	
(1) Fruit number per plant								
				Average				Average
IS_f	2.5	3.0	3.1		1.5	2.1	1.8	
IS_{fs}	2.8	3.0	3.0		2.1	2.1	1.9	
IS_r	2.8	2.7	2.6		2.0	1.8	1.6	
IS_h	2.8	2.9	2.5		1.8	2.0	2.0	
				2.8 A (y)				1.9 B

Y *** (z) IS ns P ns Y × IS ns Y × P ns IS × P ns Y × IS × P ns

(y) : Capital letters indicate significantly differences among Y.

(2) Fruit size (cm)	P_{50} (2005)	P_{75} (2005)	P_{100} (2005)	P_{50} (2006)	P_{75} (2006)	P_{100} (2006)
IS_f	13.7 b**b**B (y)	15.1 b**a**A	15.8 a**a**A	16.0 c**a**A	15.7 d**a**A	16.4 d**a**A
IS_{fs}	15.0 a**b**A	14.8 b**b**B	16.3 a**a**B	14.3 d**b**A	17.8 c**a**A	17.7 c**a**A
IS_r	14.4 a**b**B	15.0 b**b**B	16.1 a**a**B	18.6 b**c**A	22.0 a**a**A	20.9 a**b**A
IS_h	14.2 a**a**A	17.1 a**a**A	16.2 a**a**A	22.4 a**a**A	20.1 a**a**A	19.7 a**a**A

Y *** (z) IS *** P *** Y × IS *** Y × P * IS × P *** Y × IS × P ***

(y): Small, bold small, and capital letters indicate significantly differences among IS in each Y and P, among P in each Y and IS, and among Y in each IS and P, respectively.
(z): ns, *,**,*** non-significant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

for these applications. Continuing irrigation during the ripening period did not evidently increase fruit size, and similar fruit size could be obtained by applying 75% of full irrigation rather than 100%.

The results of mean fruit weight, which ranged from 1329 g to 3753 g, showed similarity with the fruit size results. Heavier fruit was obtained in the treatments of IS_r and IS_h. Continuing irrigation during the ripening period did not considerably increase the fruit weight, and similar fruit weight was obtained in the P_{75} and P_{100} applications.

The mean fruit yield varied between 2471 g and 6784 g per plant (19.0-52.2 t ha^{-1}). The IS treatments and the P applications significantly affected fruit yield. In addition, the Y × IS interactions were found significant. In the first year, the variation of fruit yield was not significantly related with the IS treatments. In the second year, higher fruit yields were obtained in the treatments of IS_r and IS_h and fruit yield variations were not significant for these two treatments. Higher fruit yields were also obtained in the P_{75} and P_{100} applications than those of the P_{50} application. Variations between the P_{75} and P_{100} applications were not found significant. As a result, continuing irrigation during the ripening period (IS_h) did not significantly increase fruit yield instead of non irrigation of this period (IS_r).

Fruit quality components: The results of the total soluble solids and titratable acidity are shown in Table 6 and 7, including statistical analysis. In addition, the results of sensory characteristics are also given in Table 8.

Table 5. Results of fruit weight and yield

Irrigation season (IS)	Year (Y)					
	2005			2006		
	Percentage of full irrigation (P)					
	P_{50}	P_{75}	P_{100}	P_{50}	P_{75}	P_{100}
(1) Fruit weight (g)						
IS_f	1575 a**a**A [y]	1417 c**a**B	1763 b**a**A	1729 c**a**A	1927 c**a**A	2035 c**a**A
IS_{fs}	1338 a**b**A	1690 bc**ab**B	1873 ab**a**A	1329 d**c**A	2313 b**a**A	1765 c**b**A
IS_r	1627 a**b**B	1939 ab**ab**B	2175 a**a**B	2884 b**b**A	3536 a**a**A	3753 a**a**A
IS_h	1560 a**b**B	2155 a**a**B	1988 ab**a**B	3466 a**a**A	3269 a**a**A	3271 b**a**A

$Y^{***\,(z)}$ IS^{***} P^{***} $Y \times IS^{***}$ $Y \times P^{ns}$ $IS \times P^{***}$ $Y \times IS \times P^{**}$

[y]: Small, bold small, and capital letters indicate significantly differences among IS in each Y and P, among P in each Y and IS, and among Y in each IS and P, respectively.

(2) Fruit yield per plant (g)

Irrigation season (IS)	2005 P_{50}	2005 P_{75}	2005 P_{100}	2006 P_{50}	2006 P_{75}	2006 P_{100}
IS_f	3841	4368	5511	2471	4050	3662
IS_{fs}	3858	4735	5526	2810	4815	3354
IS_r	4339	5345	5394	5662	6066	6005
IS_h	4534	5878	5007	6154	6784	6531

$Y^{ns\,(z)}$ IS^{***} P^{***} $Y \times IS^{***}$ $Y \times P^{ns}$ $IS \times P^{ns}$ $Y \times IS \times P^{ns}$

	Interactions of Y × IS		Differences among percentage of full irrigation		
	2005	2006	P_{50}	P_{75}	P_{100}
IS_f	4573 aA [y]	3394 bB	4209 **b** [x]	5255 **a**	5124 **a**
IS_{fs}	4706 aA	3660 bB			
IS_r	5026 aB	5911 aA			
IS_h	5140 aB	6490 aA			

[y]: Small and capital letters indicate significantly differences among IS in each Y and among Y in each IS, respectively.
[x]: Bold small letters indicate significantly differences among P.
[z]: ns, *,**,*** non-significant or significant at P ≤ 0.05,0.01,0.001, respectively.

The mean total soluble solids content of the fruit flesh varied from 6.0 to 9.2%. The soluble solids content did not differ significantly among experimental years. The effects of irrigation season (IS) and percentage of full irrigation water requirements (P) on the soluble solids content were found statistically significant. Besides these, the significant interactions of Y × P and IS × P were also determined. The highest soluble solid contents were obtained as 8.8% in the P_{75} application in the first year and as 8.5% in the P_{100} application in the second year. The soluble solids content did not significantly differ among the treatments of IS in the application of P_{75}. The highest soluble solids contents were found in the IS_{fs} treatment for the P_{50} application and in the IS_f treatment for the P_{100} application. In the P_{75} and P_{100} applications, variations between the soluble solids contents obtained in the IS_r and IS_h were not significant. On the other hand, in the IS_r and IS_h treatments, the soluble solids contents were higher in the P_{75} application than those of the P_{50} and P_{100} applications. These results should demonstrate that continuing irrigation during the ripening period did not significantly change the soluble solids content for

Table 6. Results of the soluble solids content (%)

Irrigation season (IS)	Year (Y)					
	2005			2006		
	Percentage of full irrigation (P)					
	P_{50}	P_{75}	P_{100}	P_{50}	P_{75}	P_{100}
IS_f	7.0	8.2	9.2	8.2	8.2	9.1
IS_{fs}	8.3	8.9	7.6	8.1	8.1	8.5
IS_r	7.9	9.1	6.8	7.4	7.9	8.4
IS_h	7.5	8.9	6.9	6.0	6.6	7.8

Y^{ns} [z] IS *** P ** $Y \times IS^{ns}$ $Y \times P$ *** $IS \times P$ * $Y \times IS \times P^{ns}$

Interactions of Y × P

	2005	2006
P_{50}	7.7 **b** A [y]	7.4 **b** A
P_{75}	8.8 **a** A	7.7 **b** B
P_{100}	7.6 **b** B	8.5 **a** A

Interactions of IS x P

	P_{50}	P_{75}	P_{100}
IS_f	7.6 ab **b** [x]	8.2 a **b**	9.2 a **a**
IS_{fs}	8.2 a **a**	8.5 a **a**	8.1 b **a**
IS_r	7.7 a **ab**	8.5 a **a**	7.6 b **b**
IS_h	6.8 b **b**	7.8 a **a**	7.4 b **ab**

[y]: Bold small and capital letters indicate significantly differences among P in each Y and among Y in each P, respectively.
[x]: Small and bold small letters indicate significantly differences among IS in each P and among P in each IS, respectively.
[z]: ns, *,**,*** non-significant or significant at $P \leq 0.05, 0.01, 0.001$, respectively.

the P_{75} and P_{100} applications, but applying 75% of full irrigation water amount instead of full irrigation could increase the total of the soluble solids content.

The mean titratable acidity in the fruit flesh ranged from 0.09 to 0.16% (as citric acid). Differences in titratable acidity were significant for experimental years (Y) and the treatments of irrigation season (IS), except for the P applications. The interactions of Y × IS, Y × P, and IS × P were also found to be significant. The values of titratable acidity were higher in the second year in the treatments of IS_f and IS_{fs}. The differences among the IS treatments were not significant in the first experimental year and those among the P applications were also not significant in the second year. The highest titratable acidities were obtained in the P_{75} application in the first year and in the IS_f treatment in the second year.

The mean ratings of sensory characteristics varied between 1.3 and 4.3 (Table 8). In the first experimental year, the ratings of sensory characteristics increased in the IS_f treatment, and decreased in the IS_r and IS_h treatments with an increase in the percentage of irrigation water applied (P). In the IS_f treatment, the highest rating was obtained with the P_{75} application. In the second experimental year, the highest sensory characteristics ratings were obtained in the P_{75} application for all treatments of the irrigation season except IS_h. The results of both years generally indicate that the ratings of sensory characteristics obtained for the treatments of IS_f, IS_{fs}, and IS_r should be considered close to each other for all P applications. Irrigation during ripening period could decrease those ratings.

Water use efficiency: The results of water use efficiency are shown in Table 9. These values varied between 5.6 and 12.9 kg m^{-3}. Water use efficiencies decreased with an increase in irrigation water applied in each irrigation for the IS_r and IS_h treatments in both years. In the IS_f treatments, the highest ratings were obtained in the P_{100} application in the first year and in

Table 7. Results of titratable acidity (% citric)

Irrigation season (IS)	Year (Y)					
	2005			2006		
	Percentage of full irrigation (P)					
	P_{50}	P_{75}	P_{100}	P_{50}	P_{75}	P_{100}
IS_f	0.11	0.12	0.11	0.14	0.12	0.16
IS_{fs}	0.11	0.11	0.11	0.14	0.12	0.14
IS_r	0.11	0.13	0.09	0.12	0.10	0.09
IS_h	0.12	0.12	0.09	0.12	0.12	0.11

Y *** [(z)] IS *** P [ns] Y × IS ** Y × P *** IS × P ** Y × IS × P [ns]

Interactions of Y × IS			Interactions of Y × P			Interactions of IS × P			
	2005	2006		2005	2006		P_{50}	P_{75}	P_{100}
IS_f	0.11 a B [(y)]	0.17 a A	P_{50}	0.11 **ab** B [(x)]	0.13 **a** A	IS_f	0.13 a **ab** [(v)]	0.12 a **b**	0.14 a **a**
IS_{fs}	0.11 a B	0.13 b A	P_{75}	0.12 **a** A	0.12 **a** A	IS_{fs}	0.13 a **a**	0.12 a **a**	0.13 b **a**
IS_r	0.11 a A	0.10 c A	P_{100}	0.10 **b** B	0.13 **a** A	IS_r	0.12 a **a**	0.12 a **a**	0.09 b **b**
IS_h	0.11 a A	0.12 b A				IS_h	0.12 a **a**	0.12 a **a**	0.10 b **b**

[(y)] : Small and capital letters indicate significantly differences among IS in each Y and among Y in each IS, respectively.
[(x)]: Bold small and capital letters indicate significantly differences among P in each Y and among Y in each P, respectively.
[(v)]: Small and bold small letters indicate significantly differences among IS in each P and among P in each IS, respectively.
[(z)]: ns, *,**,*** non-significant or significant at P ≤ 0.05,0.01,0.001, respectively.

Table 8. Results of sensory characteristics

Irrigation season (IS)	Year (Y)					
	2005			2006		
	Percentage of full irrigation (P)					
	P_{50}	P_{75}	P_{100}	P_{50}	P_{75}	P_{100}
IS_f	1.9	2.2	3.7	3.5	4.3	3.6
IS_{fs}	2.6	3.1	2.5	3.5	4.3	3.6
IS_r	3.7	2.7	2.1	3.8	4.3	3.0
IS_h	3.8	1.8	1.7	1.3	2.0	4.1

Table 9. Water use efficiencies (WUE, kg m^{-3})

Irrigation season (IS)											
IS_f			IS_{fs}			IS_r			IS_h		
Percentage of full irrigation (P)											
P_{50}	P_{75}	P_{100}	P_{50}	P_{75}	P_{100}	P_{50}	P_{75}	P_{100}	P_{50}	P_{75}	P_{100}
2005											
8.8	9.0	9.8	7.7	7.9	7.8	9.7	8.9	7.5	10.2	9.9	6.8
2006											
6.1	8.6	7.2	6.4	9.5	5.6	10.8	9.2	7.3	12.9	10.0	7.7

those of P_{75} in the second year. The highest ratings were also obtained in the P_{75} application for the IS_{fs} treatment in both years.

Discussion

According the results obtained in this study, vegetative growth increased with increasing the amount of water applied in each irrigation and continuing irrigation during the ripening period also furthered vegetative growth except full irrigation. This finding should be concluded to be normal as high soil water content in root zone furthers vegetative growth (Stanley and Maynard, 1990).

Irrigation until the beginning of the ripening or harvesting periods and applying 75% or 100% of full irrigation water requirements resulted in relatively big and heavy fruits. Hernandez et al., (1995) declared that considerably high soil moisture content in the root zone bears big fruits.

Irrigation up to the beginning of ripening period resulted in relatively high fruit yield and continuing irrigation during ripening period did no significantly affect fruit yield. This result is similar to the previous findings of Lester et al., (1994) and Faberio et al., (2002) who reported that soil water deficit during the ripening period did not significantly affect fruit yield.

Application of full irrigation did not significantly increase fruit yield comparing with the application of 75% of full irrigation water amount. This result is also similar to the data of Hernandez et al., (1995), Alizadeh et al., (1999), and Lei et al., (2003) that application of limited irrigation water might improve the yield compared with the use of full irrigation.

Application of 75% of full irrigation water amount until the beginning of the ripening period significantly increased the soluble solids content of the fruit flesh comparing with full irrigation during the whole vegetation season. A similar interpretation could be made for sugar content of the fruit flesh as the important part of the soluble solids is sugar for melon. Metheis and Fellman (1999) and Gil et al., (2000) reported that irrigation close to harvest causes reduction of the soluble solids in the fruit flesh of melon and limited irrigation might improve the soluble solids content.

The irrigation programs of IS_rP_{75}, IS_rP_{100}, IS_hP_{75}, and IS_hP_{100} should be appropriate with respect to fruit yields. When these four irrigation programs are compared with each other with respect to growth, the other yields and quality components, the highest soluble solids contents and the ratings of the sensory characteristics were obtained in the irrigation program of IS_rP_{75}, similar shoot and fruit numbers per plant, fruit size and fruit weight were obtained though. In addition, considerably high water use efficiency and irrigation water savings of 8% at least should be obtained in the irrigation program of IS_rP_{75}.

Considering the entirety of the results obtained in this study, irrigation from transplantation to the beginning of the ripening period and the application of 75% of full irrigation water amount is likely the most suitable irrigation program (IS_r P_{75}) for drip-irrigated Kırkağaç melon grown under semi-arid climatic conditions.

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