Tarım Bilimleri Dergisi
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Journal of Agricultural Sciences
Journal homepage:
www.agri.ankara.edu.tr/journal

Paprika Pepper Yield and Quality as Affected by Different Irrigation Levels

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ARTICLE INFO
Research Article DOI: 10.1501/Tarimbil_0000001370
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Received: 17 June 2014, Received in Revised Form: 16 December 2014, Accepted: 31 December 2014

ABSTRACT

This study was carried out to determine the effects of irrigation levels on yield and quality of paprika pepper under Harran plain conditions of Turkey. Different water stress levels under drip irrigation system were created by applying 125% of cumulative Class-A Pan evaporation (CAP_{125}), 100% (CAP_{100}), 75% (CAP_{75}) and 50% (CAP_{50}) of cumulative class-A-pan (CAP) evaporation in every 3 days. Besides, an irrigation treatment with IRSIS (Irrigation Scheduling Information System) computer program was created and applied as an alternative irrigation program. Three paprika pepper cultivars (Ace, King and Queens) were tested. Experiments were conducted in randomized blocks split plots design with 3 replications in 2005 at Koruklu Station of GAP Regional Development Administration located in Harran Plain of Şarlıurfa, Turkey. Applied irrigation water amount and ET (Evapotranspiration) values for IRSIS treatment were 874 mm and 908 mm, respectively. Applied irrigation amount and ET values of CAP_{125} and CAP_{50} were between 254-568 mm and 368-602 mm, respectively. The highest yield was obtained from IRSIS treatment with 25.63 t ha^{-1} and the lowest yield was obtained from CAP_{50} with 11.72 t ha^{-1}. The yield was significantly affected by cultivar, irrigation and cultivar × irrigation interactions. The average moisture, ASTA (American Spice Trade Association), capsaicin, vitamin C and beta-carotene contents were respectively varied between 83.96 – 84.76%, between 225.76–286.22 mg kg^{-1}, between 1404.11–2408.11 mg kg^{-1} and between 77.88–113.00 mg kg^{-1}. Beta-carotene contents were not affected significantly by the cultivars, irrigations and interactions. The effects of irrigation and interactions on vitamin C and capsaicin were not also significant while the effects of cultivar on vitamin C and capsaicin were significant at $P<0.05$ level. It was observed in this study that sufficient yield levels of paprika peppers might be achieved through implementation of proper irrigation and care practices.

Keywords: Evapotranspiration; Vitamin C; Capsicine; Class-A pan; Deficit irrigation

Farklı Sulama Seviyelerinin Paprika Biberinde Verim ve Kalite Üzerine Etkileri

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TARIM BİLİMLERİ DERGİSİ — JOURNAL OF AGRICULTURAL SCIENCES 22 (2016) 77-88

ÖZET

Bu çalışma, Harran Ovası koşullarında paprika biberinde sulama suyu seviyesinin verim ve kalite üzerine etkilerini belirlemek amacıyla yürütülmüştür. Farklı sulama suyu düzeyleri 3 günde bir Class-A-Pan (CAP)'dan olan kümülatif buharlaşmanın % 125 (CAP_{125}), % 100 (CAP_{100}), % 75 (CAP_{75}) ve % 50 (CAP_{50})'sinin damla sulama sistemi kullanılarak uygulanması şeklinde oluşturulmuştur. Ayrıca IRSIS paket programına göre oluşturulan bir sulama programı da (IRSIS) sulama konusu olarak seçilmiştir. Denemede üç paprika biber çeşidi (Ace, King ve Queens) kullanılmıştır. IRSIS konusundaki sulama suyu ve bitki su tüketimi (ET) değerleri sırasıyla 874 mm ve 908 mm' dir. CAP_{125} - CAP_{50} konularına uygulanan sulama suyu ve ET değerleri ise sırasıyla, 568-254 mm ve 602-368 mm aralığında değişim göstermiştir. En yüksek verim 25.63 t ha^{-1} ile IRSIS (Irrigation Scheduling Information System) sulamasından elde edilirken en düşük verim 11.72 t ha^{-1} ile CAP_{50} sulamasından elde edilmiştir. Çeşit, sulama ve çeşit x sulama interaksiyonun verim üzerine etkileri istatistiksel olarak önemli bulunmuştur. Ortalama nem, ASTA, kapsaisin, C-vitamini ve beta-karoten içeriği değerleri sırasıyla % 84.1, 261.1, 0.4 mg kg^{-1}, 1890.4 mg kg^{-1} and 98.9 mg kg^{-1} olarak elde edilmiştir. Beta-karoten içerikleri çeşit, sulama ve interaksiyonlardan önemli düzeyde etkilenmemiştir. Sulama ve interaksiyonların C vitamin ve kapsaisin üzerine etkileri de önemsizken çeşidin C vitamini ve kapsaisin üzerine etkileri $P<0.05$ düzeyinde önemli bulunmuştur. Sonuçlar uygun sulama ve bakım işlemlerinin zamanında yerine getirilmesiyle paprika biberinde arzu edilen verim düzeylerinin yakalanabileceğini göstermiştir.

Anahtar Kelimeler: Bitki su tüketimi; C-vitamini; Kapsaisin; A-sınıfı buharlaşma; Kısıntılı sulama

1. Introduction

Irrigation is the most significant input in agricultural activities to improve the yields. Throughout the world, about 70% of available water resources are allocated to agricultural activities, especially to irrigation. Today, it is almost impossible to increase the cultivated lands, therefore researches have to be done to improve unit area-yields to increase the total yields.

Şanlıurfa Province of Turkey has insufficient precipitations during the growth seasons of vegetables. Therefore, irrigation is an essential component of plant production activities of the region. Irrigation scheduling (amount and timing) is the key issue to get the highest yields per unit area. Plant water consumption is the essential parameter of irrigation scheduling works and it may vary based on climate factors and plant growth stages. Thus, plant water consumption values should separately be determined for each climate zone and such a case is especially significant in arid and semi-arid regions.

Unconscious irrigations have various negative impacts on soil and water resources (salinity, environmental pollution, waste of water) and sustainability of agricultural activities. Such irrigations also result in root crown rot *(Phytophthora capsici L.)* especially in peppers (Rista et al 1995).

Pepper is the largest culture crop in Harran Plain of Turkey and mostly surface irrigation methods are used in pepper irrigation. However, there is an urgent need to move on to drip irrigation to prevent excessive water use and resultant plant diseases. Statistical data reveal that Turkey has about 2% of world pepper production and of this amount 15% is produced in GAP (Southeastern Anatolia Project) region and of that amount 37% is produced in Şanlıurfa Province (FAOSTAT 2005).

Paprika peppers are sensitive to low temperatures and usually considered as a proper plant for the regions with temperature ranges between 24-30 °C. They constitute a significant raw material of world food industry and usually consumed as ground pepper, chili pepper and chili sauces. They are largely consumed in developed countries, especially in the USA. The greatest producers are Mexico, Zambia, Hungary and Spain. Problems experienced in production and processing of paprika peppers in these countries enforced the search for new production sites. Recently, Israel achieved to get paprika pepper oil with new technologies and such a development has made this oil an essential raw material for drug and cosmetic industries. Southeastern Anatolia Region of Turkey has highly available climate conditions for paprika pepper production and paprika pepper has newly been getting popular throughout the region. Therefore, the present study was conducted to investigate the effects of different irrigation levels on yield, quality and plant physiological characteristics of paprika pepper cultivars of Ace, Queen and King.

2. Material and Methods

The present research was conducted over the experimental fields of Koruklu Station of GAP Regional Development Administration located in Harran Plain of Şanlıurfa Province. The station is located at 36° 42' North latitude and 38° 58' East longitude and has an altitude of 410 m. Although the province is within Southeastern Anatolia climate zone, Mediterranean climate is dominant in the region. Summers are hot and dry and winters are mild and precipitated.

With regard to climate data, long-term averages and the averages for growth period are provided in Table 1. The region has an annual total precipitation of 365.2 mm and of this amount 17.3% is received in fall, 52.8% in winter, 28.8% in spring and 1.1% in summer. Annual average temperature is 17.2 °C, the highest average temperature is 46.8 °C and the lowest average temperature is -16.8 °C. Annual average relative humidity is 51% and annual total evaporation is 1848.8 mm.

The research site has clayey soils with pH values between 7.3-7.8, low organic matter content, high cation exchange capacity and infiltration rates of between 12-116 mm h^{-1}. Physical characteristics of experimental soils are provided in Table 2. Available

Table 1- Climate data for pepper growth period and long-term averages

Çizelge 1- Büyüme sezonu ve uzun dönem iklim verileri

Climate parameter	*June*	*July*	*August*	*September*
	Long-term (1929-2004)			
Minimum temperature (°C)	9.4	11.0	9.2	3.4
Maximum temperature (°C)	45.4	46.8	46.7	44.0
Average temperature (°C)	28.0	31.4	30.4	25.6
Precipitation (mm)	2.5	0.1	-	0.1
Relative humidity (%)	35	33	36	34
Wind speed (m s^{-1})	2.5	2.6	2.1	1.5
	Growth period (2005)			
Minimum temperature (°C)	15.1	20.4	20.0	14.1
Maximum temperature (°C)	38.5	43.7	43.5	32.8
Average temperature (°C)	27.4	33.0	32.1	24.3
Precipitation (mm)	0	0	0	0
Relative humidity (%)	35.9	32.8	44.7	47.0
Wind speed (m s^{-1})	2.6	2.8	1.7	1.1

Table 2- Soil physical characteristics of the research site

Çizelge 2- Araştırma sahası toprak fiziksel özellikleri

Soil layers		*Particle size distribution*			*Texture class*	*FC*	*PWP*	*WHC*
(cm)	*Bulk density (g cm^{-3})*	*Sand (%)*	*Silt (%)*	*Clay (%)*		*(%)*	*(%)*	*(%)*
0-30	1.32	8.8	30.5	60.7	Clay	33.74	20.28	13.46
30-60	1.37	10.0	33.5	56.5	Clay	32.27	21.12	11.15
60-90	1.31	10.3	27.9	61.8	Clay	32.39	21.85	10.54

water holding capacity of the soil at 90 cm soil profile was calculated as 120 mm.

Three different world-wide common pepper cultivars (Ace, Queen and King) were used as the plant material of the study. Papri-Queen, Papri-King and Papri-Ace are considered high quality cultivars and can command relatively high prices under good management. Papri-Queen is more disease resistant, but lower yielding than Papri-King, so more appropriate for small-scale farmers. Papri-Queen seeds may have problems in uniformity, pungency and yield and a "genetic shift" in seed may lead to deterioration in quality (Langmead 2003). Seedlings were planted on 10th of June. Irrigation water was supplied from a well within the research station. The water quality class was found to be as C_2S_1 with medium salinity and low alkalinity (U.S. Salinity Lab. Staff 1954). Drip irrigation was used in irrigations.

Experimental site was prepared for planting with a cultivator and gobble-disc in May. Three manual hoeing were performed, the first one at the end of June, the second one on 15th of July and the last one on 10th of August. A plant disease was not encountered during the experiments. Troper was applied at a rate of 2500 g ha^{-1} to prevent root diseases and Mica super was applied at 1000 cc ha^{-1} dose for weed control just before seedling transplantation on the soil surface of experimental plots.

Plots were 70 m long and there were 10 rows in each plot with 70 cm row spacings and 25 cm on-row plant spacing. A 3-meter spacing was provided between the plots. Middle 6 rows were hand-picked since side rows were omitted as side effect. A drip line (with 50 cm dripper spacing and 4 L h^{-1} dripper discharge) was placed to each row. Daily evaporations were measured through a Class-A-Pan (CAP) within the research station. As base fertilizer, 400 kg ha^{-1} ammonium sulphate (33%) was applied just before sowing and 300 kg ha^{-1} 20-20-0 composed fertilizer was applied through fertigation at five equal doses as dressing fertilizer. Experiments were conducted in randomized blocks split plots design with 3 replications. Cultivars were placed in main plots and irrigation levels were placed in sub-plots.

Seasonal water deficit treatments were arranged as the 50% (CAP_{50}), 75% (CAP_{75}), 100% (CAP_{100}) and 125% (CAP_{125}) of 3-days cumulative evaporation from Class-A-Pan (CAP). Another irrigation treatment was created by using IRSIS irrigation scheduling program. Thus, 5 different irrigation treatments were applied to 3 different pepper cultivars. Experimental irrigation treatments were initiated when the plant cover ratio reached to 30% level (for better plant emergence) (15th of July). Until such a ratio, entire plants were irrigated at the optimum levels with equal amounts of water. A total of 162.5 mm irrigation water was applied until July 15, 2005 as not to create a water stress over the plants. IRSIS irrigation treatment was created by using long-term meteorological data of Akçakale meteorology station and FAO Penman-Monteith model. Amount of water to be applied in each irrigations was calculated by using the Equation 1.

$$I = E_{pan} * A * K_{cp} * P \qquad (1)$$

Where; I, amount of irrigation water (L); E_{pan}, cumulative evaporation (mm); K_{cp}, plant-pan coefficient (1.25, 1, 0.75 and 0.50); P, plant cover ratio (obtained by dividing canopy width with row spacing); A, plot size (m^2).

Soil moisture measurements were taken up to 120 cm soil depth at planting, before each irrigation and at hand picking, gravimetrically. Actual water consumption of pepper was calculated by using water-budget equation (Equation 2).

$$ET = I + P - D \pm R \pm \Delta s \qquad (2)$$

Where; ET, evapotranspiration (mm); I, irrigation water (mm); P, precipitation (mm); D, deep percolation (mm); R, runoff (mm); Δs, soil moisture variation between two sampling (mm).

Although the effective root depth of pepper was 60 cm, soil moisture measurements were made till 120 cm soil depth in order to consider deep percolation and runoff was taken as zero since drip irrigation was used. Capillary rise was not also taken into consideration since there were not any groundwater problems in the field.

Plant height and stem diameter were measured over 5 plants selected from the middle sections of all treatment plots. Plant height was measured as the height from the root collar to top of the plant and average of replications was taken. A digital caliper was used to measure stem diameters at 5 cm above the root collar. Plant moisture analysis was carried out in accordance 1997-ASTA Method 2.0, color value with 1997-ASTA Method 20.1, Capsaicin analysis with 1997-ASTA Method 21.3 (ASTA 1997), vitamin C with Ruckemann (1980), Beta Carotene analysis with Bushway (1986) at Ankara Municipal Food Control Laboratories.

3. Results and Discussion

3.1. Irrigation water-ET-yield relationships

A total of 162.5 mm water was applied to each treatment until 30% plant cover level on 15th of July. Total seasonal irrigation water applications for the treatments IRSIS, CAP_{125}, CAP_{100}, CAP_{75} and CAP_{50} were respectively realized as 874, 568, 506, 383 and 254 mm. Seasonal ET values varied based on cultivars. The highest ET value was observed in IRSIS treatment of Queen cultivar with 927 mm and the lowest value in CAP_{50} of Queen with 376 mm (Table 3).

Optimal irrigation scheduling is very crucial for conserving water, nutrients, as well as improving the productivity and quality of the plants. Many studies investigated the effect of irrigation frequency on the growth and yield of paprika plants grown in the fields (Jaimez et al 1999; Sezen et al 2006). Yildirim et al (1994) carried out a drip irrigation study on pepper and reported the applied amounts of waters as between 395.4 and 718.6 mm. Kirnak et al (2003) implemented a drip irrigation study on local peppers of Şanlıurfa Province with three different irrigation intervals (2, 4 and 6 days) and three different Pan-coefficients (1.25, 1.0 and 0.75) and reported seasonal water applications of between 652-1010 mm, seasonal ET of between 726-1069 mm. Similar results were also observed by Degirmenci & Sozbilici (1995) with researches over the same plain. Wierenga & Hendrickc (1985) investigated the impacts of irrigation levels on yield and quality of chili peppers and observed the highest yields at irrigation levels of between 800-950 mm.

Average marketable yield also varied based on cultivar and irrigation water. The highest value was observed in IRSIS treatments of Ace with 38.13 t ha^{-1} and the lowest value was seen in CAP_{50} of King with 8.74 t ha^{-1} (Table 4). A second degree polynomial relationship was identified between marketable yield and ET (Figure 1). Increasing irrigation water resulted in increasing discard ratios.

Table 3- Irrigation water, ET and yield values for paprika pepper

Çizelge 3- Paprika biberi sulama suyu, ET ve verim değerleri

Treatment	*Seasonal irrigation water (mm)*	*Seasonal ET (mm)*			*Average marketable yield (t ha^{-1})*			*Discard (kg ha^{-1})*		
		Ace	*King*	*Queen*	*Ace*	*King*	*Queen*	*Ace*	*King*	*Queen*
IRSIS	874	920	907	927	38.13	19.57	22.33	750	1680	700
CAP_{125}	568	613	615	609	27.60	14.50	26.48	710	1280	550
CAP_{100}	506	567	548	561	18.03	12.07	19.54	350	640	360
CAP_{75}	383	469	570	477	14.84	10.29	16.69	340	350	190
CAP_{50}	254	377	381	376	12.95	8.74	14.24	210	310	240

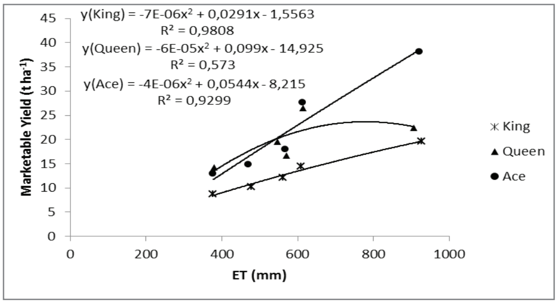

Figure 1- ET-yield relationships for paprika pepper cultivars

Şekil 1- Paprika biber çeşitleri için ET-verim ilişkileri

Considering the actual climate data of the growth season, irrigation treatments (IRSIS, CAP_{125}, CAP_{100}, CAP_{75} and CAP_{50}) were evaluated by IRSIS software and effects of water deficit (Eta ETm^{-1}) on yield (Ya Ym^{-1}) and stress periods were investigated. Water-yield relationships and water application efficiencies are provided in Table 4.

According to Table 4, (1) Since the water deficit in CAP_{50} treatment already exceeded 50%, the treatment should not be implemented, (2) IRSIS evaluations based on actual seasonal data revealed that excessive water was applied and therefore deep percolation was seen (77 mm), (3) Yield response factor (ky) was assumed to be 1.10 while running IRSIS simulation model, but actual data revealed a ky value of 1.29. Such a case indicated that lower value was selected in IRSIS simulations for the region.

Seasonal variations in water depletion within root region of different irrigation treatments were determined by IRSIS simulations and presented in Figure 2. As indicated in figure, water deficit was observed in all irrigation treatments, except for IRSIS treatment, from planting to end of flowering period with intensive vegetative growth. Moisture depletion within the root zones of deficit irrigation treatments increased with the level of deficit.

Shmueli & Goldberg (1972) carried out a drip irrigation research on peppers in Israel under dry conditions and applied four different irrigation levels (0.83, 0.95, 1.33 and 1.75 times of Class-A-Pan

Table 4- Evaluation of irrigation treatments with IRSIS software

Çizelge 4- IRSIS programı ile sulama uygulamalarının değerlendirilmesi

	Eta ETm^{-1}	*Irrigation water (mm)*	*Ya Ym^{-1}*	*Irrigation efficiency (%)*	*Drainage water (mm)*	*Runoff water (mm)*
IRSIS planning based on long-term climate data	1.00	794	100.0	100.0		
IRSIS planning based on actual climate data of the growth season	0.96	858	96.2	91.0	77	0
Evaluation of CAP_{125} treatment with IRSIS	0.74	583	65.9	98.1	11	0
Evaluation of CAP_{100} treatment with IRSIS	0.68	505	58.6	99.8	1	0
Evaluation of CAP_{75} treatment with IRSIS	0.55	363	44.0	100.0	0	0
Evaluation of CAP_{50} treatment with IRSIS	0.38	220	27.0	100.0	0	0

Eta, actual evapotranspiration; ETm, maximum evapotranspiration; Ya, actual yiled; Ym, maximum yield

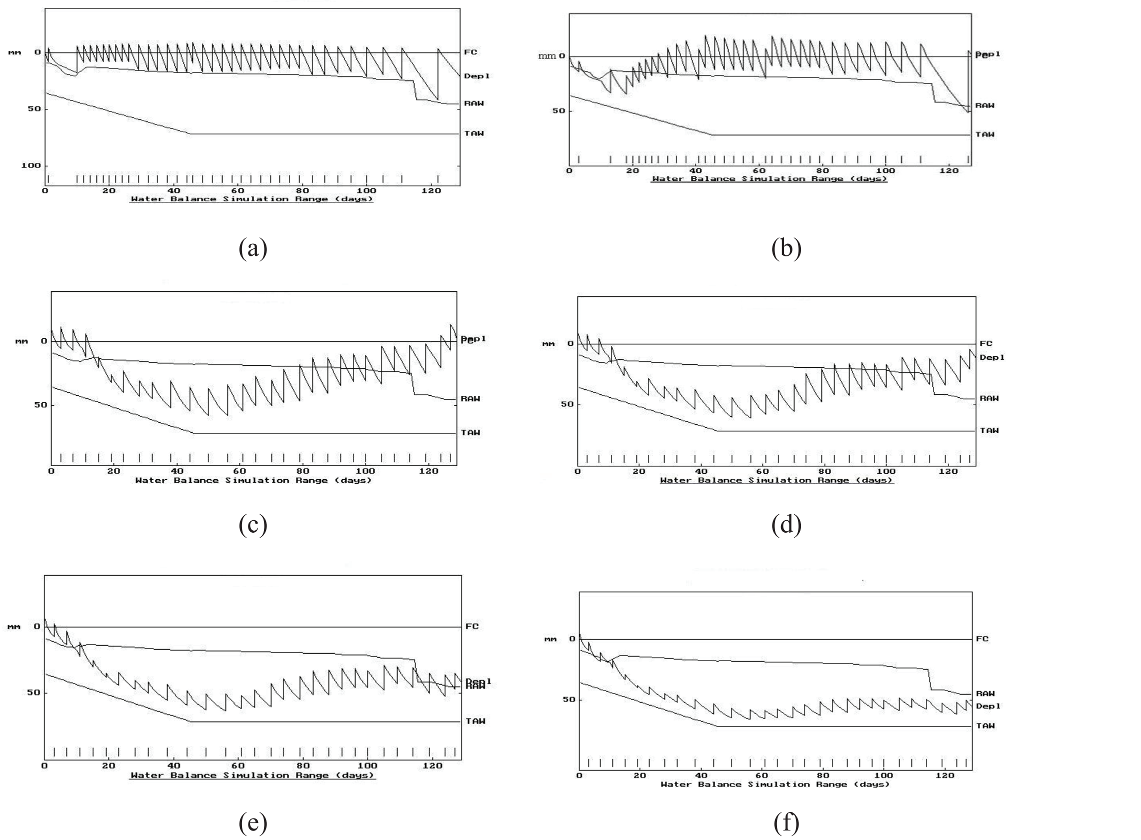

Figure 2- IRSIS simulations of irrigation treatments a, based on long-term climate data; b, based on actual growing season data; c, CAP_{125} based on actual data; d, CAP_{100} based on actual data; e, CAP_{75} based on actual data; f, CAP_{50} based on actual data (FC, field capacity; RAW, readily available water; TAW, total available water; Dep1, moisture depletion)

Şekil 2- Sulama uygulamalarının IRSIS sulama programında değerlendirilmesi a, uzun-yıllar iklim verilerine göre; b, 2005 yılı gerçek verilerine göre; c, 2005 yılı gerçek verilerine göre CAP_{125}; d, 2005 yılı gerçek verilerine göre CAP_{100}; e, 2005 yılı gerçek verilerine göre CAP_{75}; f, 2005 yılı gerçek verilerine göre CAP_{50}. (FC, tarla kapacitesi; RAW, mevcut yarayışlı Su; TAW, toplam yarayışlı su; Dept1, nem azalması)

evaporation) and indicated a yield response factor of 1.33. Palada & O'Keefe (2001) investigated the response of hot pepper cultivars to levels of drip irrigation in the Virgin Islands and observed increasing yield trends with increasing amounts of irrigation water. Similarly, increasing yield levels were also reported with drip irrigation in previous studies (Palada et al 2001; Palada & O'Keefe 2003). Park & Jung (2000) carried out a study in Korea and indicated the significance of moisture profile within root region for optimum irrigation programs especially for dry regions.

Effects of irrigation, cultivar and interactions on yield and plant physical characteristics are provided in Table 5. While the effects of cultivar on yield were significant at $P<0.05$ level, effects of irrigation and irrigation x cultivar interaction were found to

Table 5- Effects of irrigation, cultivar and interactions on yield and physiological characteristics

Çizelge 5- Sulama, çeşit ve interaksiyonların verim ve fizyolojik özellikler üzerine etkileri

Treatments	*Mean yield ($t\ ha^{-1}$)*	*Plant height (cm)*	*Stem diameter (mm)*	*Canopy diameter (cm)*
Irrigations				
IRSIS	25.63 a*	65.22 b	13.75 b	54.65 b
CAP_{125}	22.01 b	67.88 a	15.21 a	64.85 a
CAP_{100}	16.10 c	65.00 b	13.22 bc	65.83 a
CAP_{75}	13.65 cd	66.88 ab	12.95 cd	63.88 a
CAP_{50}	11.72 d	59.44 c	12.60 d	55.65 b
Mean	17.82	64.889	13.549	60.978
LSD (0.05)	0.4830	2.379	0.6184	2.319
CV (%)	19.99	3.77	4.69	3.91
Cultivar				
Ace	21.84 a	68.26 a	14.46 a	63.93 a
King	12.18 b	63.06 b	13.65 a	61.13 b
Queen	19.45 a	63.33 b	12.52 b	57.87 c
Mean	17.82	64.88	13.549	60.978
LSD (0.05)	0.4830	2.762	1.093	2.581
CV (%)	19.99	3.77	4.69	3.91
Interactions				
Ace × IRSIS	37.38 a	65.00 de	14.00 bcd	55.90 c
Ace × CAP_{125}	26.89 b	67.33 bcde	15.00 ab	64.33 b
Ace × CAP_{100}	17.68 cde	71.00 ab	14.90 abc	67.97 ab
Ace × CAP_{75}	14.50 defg	72.66 a	13.53 d	67.07 ab
Ace × CAP_{50}	12.74 efgh	65.33 de	14.90 abc	64.50 b
King × IRSIS	17.89 cde	63.66 ef	13.90 cd	63.07 cd
King × CAP_{125}	13.22 defgh	66.33 cde	15.53 a	65.27 b
King × CAP_{100}	11.43 fgh	60.33 fg	13.267 d	65.53 b
King × CAP_{75}	9.94 gh	69.00 abcd	13.900 cd	69.87 a
King × CAP_{50}	8.43 h	56.00 h	11.67 e	51.83 de
Queen × IRSIS	21.63 bc	67.00 bcde	13.37 d	55.00 cd
Queen × CAP_{125}	25.93 b	70.00 abc	15.10 a	64.97 b
Queen × CAP_{100}	19.18 cd	63.66 ef	11.50 e	64.00 b
Queen × CAP_{75}	16.50 cdef	59.00 gh	11.43 e	54.73 cd
Queen × CAP_{50}	14.00 defgh	57.00 gh	11.23 e	50.633 e
Mean	17.94	64.88	13.549	60.978
LSD (0.05)	13.86	4.12	1.071	4.017
CV (%)	11.24	3.77	4.69	3.91

*, the means indicated with the same letter are not statistically significant

be significant at $P<0.01$ level. Average pepper yield was observed as 17.82 $t\ ha^{-1}$. The highest yield was observed in IRSIS irrigation with 25.63 $t\ ha^{-1}$ and it was followed by CAP_{125} irrigation with 22.01 $t\ ha^{-1}$. Decreasing yields were observed in CAP irrigations with decreasing irrigation waters. While IRSIS and CAP_{125} were placed in different yield groups, CAP_{100} - CAP_{75} and CAP_{50} - CAP_{75} were placed into same groups. The lowest yield was seen in CAP_{50} with 11.72 $t\ ha^{-1}$.

While the cultivars Ace and Queen were placed in the same yield group, King was placed in a different group. The highest yield was observed in Ace with 21.84 t ha^{-1} and the lowest yield was seen in King with 12.19 t ha^{-1}. With regard to interactions, while Ace × IRSIS interaction had the highest yield with 37.38 t ha^{-1}, King × CAP_{50} interaction had the lowest yield with 8.43 t ha^{-1}.

3.2. Effects of irrigations on physiological characteristics

While the cultivar had significant effects on plant height and diameter at $P<0.05$, irrigation and irrigation × cultivar interaction had significant impacts at $P<0.01$ level. Average plant height was observed as 64.8 cm. The highest value was seen in CAP_{125} irrigation with 67.8 cm and it was followed by IRSIS irrigation with 65.2 cm. The lowest value was observed in CAP_{50} treatment with 59.4 cm. IRSIS, CAP_{100} and CAP_{75} were placed into the same plant height group.

While the cultivars King and Queen were placed into the same height group, Ace was placed into another group. The highest plant height was observed in Ace with 68.2 cm and the lowest in King with 63.1cm. With regard to interactions, while Ace × CAP_{75} interaction yielded the highest plant height with 72.6 cm, the lowest value was observed in King × CAP_{50} interaction with 56 cm.

Average plant stem diameter was observed as 13.5 mm with the highest value in CAP_{125} irrigation (15.2 mm) and the lowest value in CAP_{50} irrigation (12.6 mm). While IRSIS and CAP_{125} were placed into different diameter groups, CAP_{75} and CAP_{100} were placed into the same group.

While the cultivars King and Ace were placed into the same diameter group, Queen was placed into a different group. The highest value was observed in Ace with 14.4 mm and the lowest in Queen with 12.5 mm. With regard to interactions, King × CAP_{125} interaction yielded the highest plant stem diameter with 15.5 mm and Queen × CAP_{50} interactions had the lowest diameter with 11.2 mm.

Effects of irrigation, cultivar and irrigation × cultivar interactions on plant canopy diameter were found to be significant at $P<0.01$ level. Average canopy diameter was observed as 60.9 cm. The highest value was obtained from CAP_{100} treatment with 65.8 cm and it was followed by CAP_{125} treatment with 64.8 cm. The lowest value was seen in CAP_{50} treatment with 55.6 cm. While IRSIS and CAP_{50} were placed into the same canopy diameter group, other irrigation treatments (CAP_{125}, CAP_{100} and CAP_{75}) were placed into another group.

With regard to canopy diameters of cultivars, all of them were placed into different groups. The highest value was observed in Ace with 63.9 cm and the lowest in Queen with 57.8 cm. Considering the interactions, Ace × CAP_{100} had the highest canopy diameter with 67.9 cm and Queen × CAP_{50} had the lowest canopy diameter with 50.6 cm.

Yohannes & Tadesse (1998) investigated yield and yield components of tomato under different irrigation systems and indicated drip irrigation as the best method for vegetable irrigation. Rista et al (1995) reported lower root collar (*Phytophthora capcisi*) incidences in drip irrigation than furrow irrigation. Current findings regarding the entire vegetative characteristics and their relationships with irrigation water comply with the findings of previous studies carried out on peppers (Bracy et al 1995; Degirmenci & Sozbilici 1995; Cevik et al 1996).

3.3. Effects of irrigations on quality parameters

As the quality parameters of paprika peppers, moisture content, ASTA value (color), capsicine, vitamin C and beta-carotene were investigated. Effects of irrigations, cultivars and interactions on quality parameters are presented in Table 6. Mean moisture content was observed as 84.1%, ASTA value as 261.1, capsicine content as 0.4 mg kg^{-1}, vitamin C content as 1890.4 mg kg^{-1} and beta carotene content as 98.9 mg kg^{-1}.

While the effects of irrigations on moisture contents were insignificant, effects of cultivar and interactions were found to be significant. The highest moisture content was observed in Ace with 85.3%. The cultivars Queen and King were statistically placed into the same moisture content group. With regard to moisture contents of interactions, Ace × CAP_{100} interaction had the highest moisture content with 85.9% and King × IRSIS interaction had the lowest value with 81.8%.

The highest ASTA value was observed in IRSIS irrigation with 286.2 and it was followed by CAP_{50} irrigation with 282.5. The lowest value was seen in CAP_{100} irrigation with 225.7. While IRSIS and CAP_{50} were placed into the same ASTA group, CAP_{75} and CAP_{125} were placed into another same group and CAP_{100} was placed into a different group.

With regard to ASTA values of the cultivars, all of them were placed into different groups. The highest value was observed in Ace with 285.5 and the lowest value was seen in Queen with 236.0. With regard to interactions, Ace × CAP_{50} had the highest value with 327.1 and Queen × CAP_{100} interaction had the lowest value with 185.3. Other interactions had values in between them (Table 6).

Table 6- Effects of irrigation, cultivar and interactions on quality parameters

Çizelge 6- Sulama, çeşit ve interaksiyonların kalite özellikleri üzerine etkileri

Treatment	*Moisture content (%)*	*ASTA*	*Capsicine (mg kg⁻¹)*	*Vitamine C (mg kg⁻¹)*	*Beta carotene (mg kg⁻¹)*
Irrigation					
IRSIS	83.96 ns	286.22 a*	0.44 ns	2117.88 ns	77.88 ns
CAP_{125}	83.70	264.34 b	0.53	2408.11	96.22
CAP_{100}	84.76	225.76 c	0.43	1840.77	113.00
CAP_{75}	84.25	247.04 b	0.41	1681.11	99.11
CAP_{50}	84.01	282.51 a	0.43	1404.11	108.44
Mean	84.140	261.178	0.452	1890.400	98.93
LSD (0.05)	-	17.85	-	-	-
CV (%)	1.250	7.03	20.81	40.27	34.08
Cultivar					
Ace	85.38 a	285.56 a	0.37 b	1837.00 ab	92.80 ns
King	83.70 b	261.93 b	0.53 a	2437.00 a	116.73
Queen	83.32 b	236.03 c	0.44 ab	1397.20 b	87.26
Mean	84.140	261.178	0.452	1890.400	98.93
LSD (0.05)	0.8561	18.51	0.1014	685.5	-
CV (%)	1.250	7.03	20.81	40.27	34.08
Interaction					
Ace × IRSIS	85.93 ab	307.33 ab	0.38 ns	2309.00 ns	72.00 ns
Ace × CAP_{125}	85.33 abc	265.36 cdef	0.37	2020.00	107.66
Ace × CAP_{100}	85.97 a	261.50 def	0.36	1715.66	105.00
Ace × CAP_{75}	85.16 abcd	266.53 cde	0.37	1682.66	71.67
Ace × CAP_{50}	84.53 abcde	327.10 a	0.39	1457.66	107.67
King × IRSIS	81.83 ef	258.20 defg	0.49	2701.66	94.67
King × CAP_{125}	83.80 cde	274.80 cde	0.71	2866.66	95.67
King × CAP_{100}	85.43 abc	230.50 gh	0.55	2358.00	146.00
King × CAP_{75}	83.43 def	260.66 defg	0.45	2201.66	136.67
King × CAP_{50}	84.03 cde	285.50 bcd	0.45	2057.00	110.67
Queen × IRSIS	84.13 cde	293.13 bc	0.46	1343.00	67.00
Queen × CAP_{125}	81.96 ef	252.86 efg	0.51	2337.66	85.33
Queen × CAP_{100}	82.90 ef	185.30 ı	0.37	1448.66	88.00
Queen × CAP_{75}	84.16 bcde	213.93 hı	0.41	1159.00	89.00
Queen × CAP_{50}	83.46 def	234.93 fgh	0.45	697.66	107.00
Mean	84.140	261.178	0.45	1890.400	98.93
LSD (0.05)	1.773	30.92	-	-	-
CV (%)	1.250	7.03	20.81	40.27	34.08

*, the means indicated with the same letter are not statistically significant; ns, not significant

Effects of irrigation, cultivar and interactions on beta carotene content were found to be insignificant. While the effects of irrigation and interactions on vitamin C and capsicine contents were found to be insignificant, effects of cultivar on those parameters were found to be significant at $P<0.05$ level. The highest vitamin C and capsicine contents were observed in cultivar King respectively with 2437.0 and 0.5 mg kg^{-1}.

The quality of paprika pepper is the key to its value and is mostly graded by the industry in terms of ASTA value. Moisture content is a factor effective in pricing. Burt (2006) reported a loss of quality in terms of not only appearance, pungency, fruit splitting and decay but more importantly of the concentration of capsanthin, capsorubin and some carotenoids resulting from increased water levels. Delfine et al (2000) reported that Capsicum *annum L* is one of the most susceptible crops to water stress because of wide transpiring leaf surface and elevated stomatal openings and yet relatively copious amounts of water may be undesirable in terms of resultant fruit yield and quality. The quality of paprika therefore depends on a moisture regime that may not be similar to the level that results in increased yields of the crop. This poses a dilemma for a farmer who is mindful of the fact that quality probably counts more than yield for the paprika crop.

4. Conclusions

Although pepper planting was performed in June, it was pointed out in this study that paprika peppers could reliably be produced in Harran Plain and it could be recommended as an alternative crop for local farmers. Irrigation program prepared by IRSIS simulation model based on long-term annual averages yielded reliable outcomes for the experimental year. It was recommended that yield-response factor (ky) should be selected as 1.29 and used in the model accordingly. Compared to IRSIS simulation model, water stress was observed in Class-A-Pan-based irrigations. Since water stress was at relatively effective levels for yield during root development and flowering periods, the 30% threshold canopy coverage ratio assumed for the initiation of irrigation programs should be increased. Since constant Kc coefficients were used in Pan-based irrigations throughout the entire season, increased water stress was observed. Therefore, different coefficients should be used for each growth period. It was observed in this study that sufficient yield levels of paprika peppers might be achieved through implementation of proper irrigation and care practices.

Acknowledgements

This work was supported by GAP Regional Development Administration.

Abbreviations and Symbols	
ASTA	American spice trade association
GAP	Southeastern anatolia project
CAP	Class-A-pan
IRSIS	Iirrigation scheduling information system
FAO	Food and agriculture organization
ET	Evepatranspiration
ETa	Actual evapotranspiration
ETm	Maximum evapotranspiration
FC	Field capacity
RAW	Readily available water
TAW	Total available water
Ya	Actual yield
Ym	Maximum yield

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