The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)

Volume 1, Pages 59-68

ICONTES2017: International Conference on Technology, Engineering and Science

CRITICAL QUALITY PARAMETERS CHANGING OF RED PEPPER IN RESPONE TO DIFFERENT IRRIGATION METHODS AND LEVELS

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Abstract: New irrigation technologies and commonly used traditional furrow irrigation methods were compared to drip irrigation in order to increase color, total dry matter, total carotenoid and vitamin C of processing red pepper widely grown in the Mediterranean part of Turkey. This research was carried out in 2010-2011 growing seasons at Tarsus in Turkey. The experimental treatments; Drip treatments consist of full irrigation (DI_{100}), deficit irrigation DI_{75}, DI_{50}, DI_{PRD50}, and DI_{FPRD50} Alternative partial root drying (DI_{PRD50}) and fixed partial root drying (DI_{FPRD50}) received 50% of DI_{100}. Irrigation was applied when 25% and 40% of the available water in the 60 cm soil profile were consumed in DI_{100} and FI_{100} treatments in drip and furrow systems, respectively and soil water replenished to field capacity in DI_{100} and FI_{100} treatments. In furrow irrigation, treatments consist of full irrigation (FI_{100}), alternative furrow (FI_{A50}) and PRD furrow (FI_{PRD50}). FI_{A50} and FI_{PRD50} received 50% of water applied to FI_{100}. In FI_{A50} the same furrows were irrigated while FI_{PRD50} irrigated alternately. The highest yields in drip and furrow systems were obtained from the DI_{100} and FI_{100} treatments, respectively. In generally, DI_{FPRD50} treatment was the highest a* value in drip irrigation system which means that fruits had more red color. On the other hand, b* values (it represents yellow color because of positive values) decreased following the first picking. In generally, the color parameters (a* and b*) of furrow irrigation treatments in the different picking times was not statistically significant. Total carotenoid rates increased with following picking time both drip and furrow irrigation systems and it is lower value under drip system than in the furrow system. Finally, results indicate that in drip irrigation DI_{100} treatment; and in furrow irrigation, FI_{100} treatment was recommended. Under water scarcity conditions, DI_{75} and FI_{PRD50} treatments can be recommended.

Keywords: Colour, processing red pepper, total carotenoid, vitamin C, water level

Introduction

Effective water usage is getting of significance in irrigation in Turkey's Mediterranean region due to the adverse impact of limited water sources on crop production. In Mediterranean territory Pepper (*Capsicum annuum* L.) cultivation is widespread and pepper is recognized highly vulnerable to water stress in agriculture (Doorenbos et al., 1986; Ferrara et al., 2011). Water stress has a great adverse effect on growing crops and it gives rise to

- Selection and peer-review under responsibility of the Organizing Committee of the conference
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significant yield losses especially in the course of vegetative, flowering or fruit setting stages (Sezen et al., 2006; Xie et al., 1999). It has been verified by numerous researches that water shortages throughout growth phase are detrimental to yield and over complete growing period it is necessary to provide sufficient water for greater outputs (Dorji et al., 2005; Sezen et al., 2014). It has been stated that lasting water stress causes considerable decrease in total fresh weight of fruit (Dalla Costa and Gianquinto, 2002) and insufficient irrigation leads to reduction in total pepper yield (Antony and Singandhupe, 2004). Adoption of a more efficient water saving techniques will allow establishing a more uniform crop stand, better quality, higher yield with existing scarce water resources (Ismail et al., 2015). Because of the fact that irrigation is highly influential on crop growth and yield, irrigation techniques and control are significant to ground and plant water status and water stress may occur due to improper irrigation. Drip irrigation which introduces continual low doses of water to the root zone that minimizes negative influences of cyclic over-irrigation and lowers greatly irrigation water used is recognized as a highly efficacious technique for irrigation and more effective than furrow irrigation (Asif et al., 2016; Kırnak et al., 2016). Farmers in Mediterranean region growing red pepper usually prefer wild flooding, furrow and basin as irrigation techniques that lead to excessive water use and less effective irrigations (Sezen et al., 2006).

Peppers are popular vegetables because of the combination of color, taste, and nutritional value. Fresh peppers are one of the vegetables with a high content of vitamin C and are a good source of pro-vitamin A carotenoids (Zhang and Hamauzu, 2003; Marin et al., 2004). Moreover, carotenoid pigments are responsible for the red color of the peppers. The main organoleptic characteristic of the pepper (*Capsicum annuum* L.) is color, an attribute of the carotenoid profile of the fruit. Peppers suffer a profound change during the course of ripening with the conversion of existing pigments. Thus, the green colour of the fruit is principally due to the presence of chlorophyll and to the carotenoids typical of the chloroplast, such as oxygenated carotenoids or xanthophylls, violaxanthin, neoxanthin, and lutein, as well as β-carotene (Minguez-Mosquera and Hornero-Me´ndez, 1993). Red peppers contain the highest amount of provitamin A (β-carotene and β-cryptoxanthin) (Conforti et al., 2007).

Materials and Methods

Experimental Site and Climate

Field experiments were conducted for 2 years (2010 - 2011) in the experimental field of Soil and Water Resources Unit of Horticultural Research Institute, located in Tarsus, Mersin province, Turkey (latitude 37°01′ N, longitude 35°01′ E and altitude 60.0 m mean sea level). Tarsus has a well-defined semi-arid climate. Mean annual precipitation is 616 mm, and 54% of total falls during the winter months. According to long-term climatic data (1952-2007), the annual evaporation, annual mean temperature and annual relative humidity of the region were 1490 mm, 17.8 ºC and 70.66%, respectively. The seasonal (April to October) average rainfall during 2010 and 2011 growing seasons are 165 and 172 mm, respectively.

Water is obtained from an open channel in the experimental station, quality is classified as “C2S1”. Also, pH of irrigation water was 8.08 and the average electrical conductivity was 0.51 dS m^{-1}.
The soil of the experimental area is clay loam clay texture with relatively high water holding capacity. Available soil water holding capacity of the experimental site was observed 120 mm in a 0.60 m soil profile. The soil water content at field capacity varied from 0.29 to 0.37 g g^{-1} and wilting point varied from 0.15 to 0.23 g g-1 on a dry weight basis for experimental area. The dry soil bulk densities ranged from 1.44 to 1.45 g cm^{-3} throughout the 60 cm soil profile.

Crop Management

Plants of *Capsicum annuum* (cv. Karaisalı) were transplanted into the plots on 15 April 2010 and 19 April 2011, respectively, in 2010 and 2011 growing seasons. The plants were grown in 70 cm rows with plants spaced 25 cm apart. Each experimental plot was designed as 10 m long and 4.9 m wide (7 rows per plot) and had a total area of 49.0 m^2 at transplanting.

Experimental Design

The experiment was set out in a completely randomized block design with four replications for both experiments. In drip irrigation, the first treatment (DI_{100}) which considered as a full irrigation, the required amount of water to bring to field capacity in the upper 60 cm soil depth when 25% of the soil available water used. Also, drip treatments consisted of deficit irrigation (DI_{75}, DI_{50}) and partial root drying (DI_{PRD50} and

DI_{FPRD50}). DI_{75} and DI_{50} received 75 and 50% of DI_{100}; and DI_{FPRD50} received 50% of DI_{100} irrigation continuously from one side of crop row; DI_{PRD50} received 50% of DI_{100} water alternately from the lateral. In furrow treatments, the (FI_{100}) treatment which considered as a full irrigation, the required amount of water to bring to field capacity in the 60 cm soil depth when 40% of the soil available water used. Deficit irrigation treatments consisted of fixed alternate furrow (FI_{A50}) and PRD furrow (FI_{PRD50}) in the furrow irrigation. FI_{A50} and FI_{PRD50} received 50% of water applied to FI_{100}. In FI_{A50} the same furrows were irrigated while FI_{PRD50} irrigated alternate furrows. Soil water content in the treatments was measured to 90 cm in 30 cm increments, using a neutron probe (Model 503 DR) before irrigation in 2010-2011 growing seasons. Initial soil water content (0-30 cm) was measured gravimetrically.

The total length of the growing seasons of processing red pepper were 203 and 198 days in the 2010 and 2011 growing seasons. After the vegetative stage, the occurrence of flowering and first fruit set stages of processing red pepper were observed at an earlier date in the deficit irrigation treatments. The detail of growth stages and picking times on processing red pepper was explained by Sezen et al. (2014).

Determination of Dry Matter Content

Dry matter content as (g 100 g^{-1}) was measured by drying samples under vacuum at 70 ^{o}C to a constant weight (AOAC, 1990).

Colour Measurement

Colour analysis was carried out by Minolta CR 400 (Osaka, Japon) colourmeter. CIELAB colour system was used to explain the colour properties of the pepper samples. In the CIELAB colour system, L*, a*, and b* define lightness (0: black; 100: white), the red/green value ((+): red; (-): green), and the yellow/blue value ((+): yellow; (-): blue), respectively.

Determination of Total Carotenoid Content

Total carotenoid of red peppers was conducted according to the previously described method of Lee et al (2001) with some modifications.75 g of fruit and 25 g water were blended for 1 min at high level. 1 g of his mixture were mixed with 9 mL of hexane solution (hexane/methanol/acetone, 50/25/25, v/v with 0.1% BHT) and then centrifuged for 10 min 4000 rpm at 4oC. The supernatant phase was used to measure the absorbance at450 nm with using of spectrophotometer (Perkin Elmer Lambda 25-UV/VIS, USA). Total carotenoid contents of the samples were calculated with following formula (1):

$$TotalCarotenoid\left(\frac{mg}{100g}\right) = \frac{Absorbance \times DF \times 1000}{E^{1/2}} \quad (1)$$

In this formula; DF, dilution factor; E1/2, extinction coefficient (2505).

Determination of Vitamin C Content

The determination of vitamin C content was carried out according to previously described method by Özdemir and Dündar (1998). Briefly, the fresh red peppers were smashed with using of high speed blender and then 1 g sample was weighed and filled up to 45 mL with 0.4% oxalic acid solution.. After that, in order to eliminate suspended materials, the mix was filtrated with paper filter. 1 mL supernatant and 9 mL dye solution were added into glass tube and finally, absorbance data of the sample was collected with spectrophotometer at 502 nm.

Statistical Analysis

Analyses of variance (ANOVA) were performed using software SPSS 20 for Windows for the different parameters and means were compared using the Duncan test. Each experiment was repeated at least three times. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here. Add methods here.

Results and Findings

Colour Values

The color values of red processing peppers collected in 2010 and 2011, treated with different drip irrigation conditions, were given in Table 1. According to different drip irrigation conditions the L* values of the processing red peppers were shown differences with regard to picking years. In the processing red peppers picked in 2010, L* values ranged between 29.75-30.66 for first picking and 27.33-30.12 for sixth picking. Effect of picking period on L* values was determined statically insignificant with exception of DI_{PRD50} treatment. In addition, effect of different treatments on L* values was not significant for processing red peppers picked in 2010. For processing red peppers picked in 2011, L* values ranged between 33.22-35.14 for first picking and 26.46-28.34 for fifth picking. After first picking of 2011 crops, there is tendency to reduce L* values. Therefore, effect of picking period on L* values was statically significant (*P<0.005*). It can be said that L* values decreased because of increasing darkness of the processing red peppers. The possible reason for that may be temperature changing for second year processing red peppers. By the way, effect of different drip irrigation treatments on L* values of processing red peppers were determined insignificant for the year of 2011. To make better comparing, two year crops values were used and according these values, DI_{50} treatment had the highest L value. This means that the processing red pepper obtained with that treatment is lighter or brighter.

Table 1. Color values of processing red peppers according to different drip irrigation treatments and years

	Picking times	Irrigation treatments (2010)					Irrigation treatments (2011)				
		DI_{PRD50}	DI_{FPRD50}	DI_{100}	DI_{75}	DI_{50}	DI_{PRD50}	DI_{FPRD50}	DI_{100}	DI_{75}	DI_{50}
L values	1	29.75^{ab}	30.66^{a}	29.75^{a}	29.95^{a}	30.11^{a}	33.35^{a}	33.22^{a}	33.74^{a}	34.22^{a}	35.14^{a}
	2	30.36^{a}	30.93^{a}	28.55^{a}	29.40^{a}	30.67^{a}	27.03^{b}	28.13^{b}	27.40^{b}	26.62^{b}	26.88^{b}
	3	30.43^{a}	30.00^{a}	26.49^{a}	28.92^{a}	30.28^{a}	27.12^{b}	27.49^{b}	26.57^{b}	26.43^{b}	28.57^{b}
	4	28.56^{bc}	30.50^{a}	29.34^{a}	30.68^{a}	29.29^{a}	27.83^{b}	29.20^{b}	27.60^{b}	27.57^{b}	27.89^{b}
	5	27.98^{c}	29.04^{a}	30.66^{a}	29.61^{a}	30.18^{a}	26.46^{b}	27.75^{b}	27.88^{b}	27.62^{b}	28.34^{b}
	6	27.63^{c}	28.70^{a}	29.67^{a}	29.63^{a}	30.12^{a}					
	Average	29.12_{A}	29.97_{A}	29.08_{A}	29.07_{A}	30.11_{A}	28.36_{A}	29.16_{A}	28.64_{A}	28.49_{A}	29.36_{A}
a values	1	26.52^{a}	26.63^{a}	24.81^{a}	26.53^{a}	24.75^{a}	35.33^{a}	34.64^{a}	32.70^{a}	33.19^{a}	36.76^{a}
	2	28.41^{a}	28.01^{a}	25.69^{a}	26.62^{a}	27.07^{a}	25.77^{b}	29.02^{b}	25.61^{b}	26.21^{b}	28.23^{b}
	3	27.21^{a}	27.03^{a}	21.97^{a}	24.17^{a}	25.52^{a}	27.88^{b}	28.55^{b}	25.98^{b}	26.18^{b}	29.50^{b}
	4	28.27^{a}	29.12^{a}	26.50^{a}	26.18^{a}	27.51^{a}	25.54^{b}	24.36^{c}	23.21^{b}	24.47^{b}	25.79^{b}
	5	26.32^{a}	26.84^{a}	26.43^{a}	25.44^{a}	27.67^{a}	25.56^{b}	28.69^{b}	27.05^{b}	26.42^{b}	26.88^{b}
	6	25.91^{a}	25.39^{a}	25.80^{a}	26.51^{a}	27.89^{a}					
	Average	27.11_{A}	27.17_{A}	25.20_{A}	25.91_{A}	26.73_{A}	28.02_{A}	29.05_{A}	26.91_{A}	27.29_{A}	29.43_{A}
b values	1	10.56^{abc}	10.83^{a}	10.92^{a}	11.38^{a}	10.18^{a}	20.10^{a}	19.58^{a}	18.98^{a}	20.58^{a}	22.18^{a}
	2	11.57^{ab}	10.57^{a}	10.56^{a}	11.09^{a}	12.22^{a}	9.93^{b}	11.64^{b}	10.34^{b}	10.38^{b}	10.13^{bc}
	3	11.81^{a}	11.21^{a}	9.48^{a}	10.33^{a}	10.99^{a}	10.36^{b}	10.36^{bc}	9.75^{b}	9.45^{b}	11.65^{b}
	4	9.84^{c}	11.31^{a}	10.45^{a}	11.59^{a}	10.76^{a}	9.01^{b}	8.74^{c}	8.77^{b}	8.93^{b}	9.48^{bc}
	5	9.70^{c}	10.16^{a}	11.86^{a}	10.19^{a}	10.56^{a}	8.64^{b}	9.80^{bc}	9.27^{b}	9.05^{b}	8.92^{c}
	6	10.10^{bc}	9.49^{a}	10.63	10.59^{a}	10.62^{a}					
	Average	10.60_{A}	10.60_{A}	10.65_{A}	10.86_{A}	10.89_{A}	11.61_{A}	12.02_{A}	11.42_{A}	11.68_{A}	12.47_{A}

Both two years were evaluated separately. Each irrigation treatment was compared according to own picking times and differences between picking times were shown as lowercase letters. For each year, averages of irrigation treatments were compared and shown as uppercase letters (P<0.05)

The processing red peppers which irrigated with different drip treatments had different a* values according different picking years. For 2010 first picking period, a* values ranged from 24.75 to 26.63, and also ranged from 25.39 to 27.89 for the sixth period. The statistical analyze showed that differences between picking periods, evaluated each irrigation subject together, were not significant. In addition, the differences between each irrigation subjects were not significant, as well. a* values of the processing red peppers picked in 2011, ranged between 33.19-36.79 for first picking period and ranged between 25.56-28.69 for fifth picking period. After first picking period, there was tendency to decrease in values of the processing red peppers. The differences between picking periods were statistically significant for year of 2011 (*P<0.05*). The a* values of the processing red peppers in 2011 were higher than the values in 2010. The highest a values were obtained in both years for DI_{FPRD50} irrigation treatment.

The b* values of the processing red peppers treated with drip irrigation treatments were given in Table 1. The values ranged from 10.18-11.38 for first picking of 2010 and also ranged from 9.49-10.63 for sixth picking of 2010. When each irrigation treatment evaluated in terms of picking period, the differences between picking periods were not significant, except DI_{PRD50} drip irrigation treatment. Moreover, the differences of mean of picking periods for drip irrigation treatments also were not statistically significant. For the processing red peppers obtained in 2011, b* values ranged between 18.98-22.18 for first picking period and 8.64-9.80 for fifth picking period. The differences between picking periods were statistically significant for year of 2011 ($P<0.05$). The second year (2011) b* values were generally higher than the values of 2010.

Effect of different furrow irrigation treatments on L*, a*, b* values of processing red peppers obtained in 2010 and 2011 were given in Table 2. According to the results, it can be said that the processing red peppers had different L* value for two planting years (2010 and 2011). First and sixth picking period L* value results of processing red peppers in 2010, ranging from 29.30 to 30.99 and 29.99-30.60, respectively. Effect of different picking periods on L* values was not significant for each furrow irrigation treatments. At the same time, the differences between means of picking periods of furrow irrigation treatments were not significant. L* values of furrow treated processing red peppers collected in 2011, which ranged 34.94-35.58 for first picking period and 26.58-26.98 for fifth picking period. For each furrow irrigation treatments, effect of picking period on L* values was significant (P<0.05). On the contrary, the differences between means of picking periods of furrow irrigation treatments were not significant in the year of 2011.

Table 2. Color values of processing red peppers according to different furrow irrigation treatments and years

	Picking times	Irrigation treatments (2010)			Irrigation treatments (2011)		
		FI_{PRD50}	FI_{A50}	FI_{100}	FI_{PRD50}	FI_{A50}	FI_{100}
L values	1	30.33 ^{a}	29.30 ^{a}	30.99 ^{a}	35.30^{a}	35.58^{a}	34.94^{a}
	2	31.12 ^{a}	30.59 ^{a}	30.59 ^{a}	26.70^{b}	26.04^{b}	27.46^{b}
	3	31.29 ^{a}	31.64 ^{a}	31.52 ^{a}	27.57^{b}	28.01^{b}	27.03^{b}
	4	28.60 ^{a}	29.46 ^{a}	29.42 ^{a}	28.59^{b}	26.37^{b}	26.95^{b}
	5	28.85 ^{a}	29.64 ^{a}	29.21 ^{a}	26.80^{b}	26.58^{b}	26.98^{b}
	6	30.30 ^{a}	30.60 ^{a}	29.99 ^{a}			
	Average	30.08$_{A}$	30.21$_{A}$	30.29$_{A}$	28.99$_{A}$	28.52$_{A}$	28.67$_{A}$
a values	1	27.60 ^{a}	24.75 ^{a}	26.65 ^{a}	31.96^{a}	35.90^{a}	32.48^{a}
	2	27.52 ^{a}	27.03 ^{a}	27.16 ^{a}	26.07^{b}	28.01^{b}	28.15^{ab}
	3	26.86 ^{a}	28.44 ^{a}	26.37 ^{a}	27.74^{ab}	24.74^{c}	25.26^{c}
	4	25.88 ^{a}	25.80 ^{a}	25.26 ^{a}	24.87^{b}	24.59^{c}	22.77^{c}
	5	26.27 ^{a}	26.71 ^{a}	25.18 ^{a}	25.95^{b}	25.16^{bc}	25.49^{c}
	6	27.86 ^{a}	27.68 ^{a}	26.17 ^{a}			
	Average	27.00$_{A}$	26.73$_{A}$	26.13$_{A}$	27.32$_{A}$	27.68$_{A}$	26.83$_{A}$
b values	1	11.29 ^{a}	10.29 ^{b}	11.16 ^{ab}	18.77^{a}	21.09^{a}	18.84^{a}
	2	11.45 ^{a}	11.72 ^{ab}	11.32 ^{ab}	9.63^{b}	9.70^{b}	10.55^{b}
	3	11.82 ^{a}	13.48 ^{a}	12.97 ^{a}	10.02^{b}	9.16^{b}	9.85^{b}
	4	9.41 ^{a}	9.86 ^{a}	9.58 ^{b}	8.89^{b}	9.09^{b}	8.32^{b}
	5	10.23 ^{a}	10.37 ^{b}	9.71 ^{b}	8.64^{b}	8.44^{b}	9.05^{b}
	6	11.15 ^{a}	11.30 ^{ab}	10.39 ^{b}			
	Average	10.89$_{A}$	11.17$_{A}$	10.86$_{A}$	11.19$_{A}$	11.49$_{A}$	11.32$_{A}$

Both two years were evaluated separately. Each irrigation treatment was compared according to own picking times and differences between picking times were shown as lowercase letters. For each year, averages of irrigation treatments were compared and shown as uppercase letters (P<0.05)

The processing red peppers which irrigated with different furrow treatments had different a* values according different picking years. For 2010 first picking period, a* values ranged between 24.75-27.60, and also ranged between 26.17-27.86 for the sixth period. The statistical analyze showed that differences between picking periods, evaluated each irrigation subject together, were not significant. In addition, the differences between each irrigation treatments were not significant, as well. a* values of the processing red peppers picked in 2011, ranged between 31.96-35.90 for first picking period and ranged between 25.16-25.95 for fifth picking period. After first picking period, there was tendency to decrease in a* values of the processing red peppers. The differences between picking periods were statistically significant for year of 2011 ($P<0.05$). The differences between means of picking periods of furrow irrigation treatments were not significant in the year of 2011. The a* values of the processing red peppers in 2011 were close the values in 2010.

The b* values of the processing red peppers treated with furrow irrigation treatments were given in Table 2. The values ranged from 10.29-11.29 for first picking period and also ranged from 10.39-11.30 for sixth picking period of 2010. When each irrigation treatment evaluated in terms of picking period, the differences between picking periods were not significant. Moreover, the differences of mean of picking periods for furrow irrigation treatments also were not statistically significant. For the processing red peppers obtained in 2011, b* values ranged between 18.77-21.09 for first picking period and 8.44-9.05 for fifth picking period. The differences between picking periods were statistically significant for year of 2011 ($P<0.05$). Effects of different furrow irrigation treatments, by comparing of mean of picking period, were not significant on b* values of processing red peppers. The second year (2011) b* values were generally higher than the values of 2010.
Color and appearance create the first impression and greatly influence the acceptability of food; hence the development of food items with attractive color and appearance is an important goal in food industry. The red color of capsicum is imparted by carotenoids with more than 50 identified structures (Arimboor et al., 2015).

Kırnak et al. (2016) studied effect of different irrigation levels on color properties of bell pepper in terms of ASTA color value described by American Spice Trade Association. They reported that type and amount of irrigation had significant effect on the ASTA color values of bell peppers. The higher ASTA color numbers refer to more intense red color for peppers.

Total Carotenoid Content

Effects of drip and furrow irrigation treatments and picking periods on total carotenoid contents (g 100 g^{-1}) of processing red peppers obtained in years of 2010 and 2011 were shown in Table 3. Total carotenoid contents of processing red peppers treated with drip irrigation demonstrated differences according to plantation years. While total carotenoid contents were determined between 15.13-22.04 mg 100 g^{-1} for first picking in the year of 2010, the value with increasing, determined between 24.16-33.10 mg 100 g^{-1} for sixth picking period. When each irrigation treatment evaluated in terms of picking period, the differences between picking periods were significant (*P<0.05*). Similarly, the differences between mean of picking periods of drip irrigation treatments were significant (*P<0.05*). For the processing red peppers obtained in 2011, total carotenoid contents ranged between 13.59-20.61 mg 100 g^{-1} for first picking period and 22.66-38.27 mg 100 g^{-1} for fifth picking period. The comparing study showed that picking periods for each drip irrigation treatments were statically significant (*P<0.05*). However, differences between means of picking periods were not significant in 2011. Similarly, Kırnak et al. (2016) reported that effects of irrigation, cultivar and interactions on β-carotene content of bell pepper were found to be insignificant.

Table 3. Total carotenoid contents of processing red peppers according to different irrigation treatments and years (mg 100 g^{-1})

Picking times	Drip Irrigation									
	Irrigation treatments (2010)					Irrigation treatments (2011)				
	DI_{PRD50}	DI_{FPRD50}	DI_{100}	DI_{75}	DI_{50}	DI_{PRD50}	DI_{FPRD50}	DI_{100}	DI_{75}	DI_{50}
1	17.79^{b}	22.04^{cd}	15.13^{d}	18.66^{c}	18.30^{c}	20.61^{b}	15.66^{c}	13.59^{b}	17.18^{a}	18.30^{b}
2	22.39^{b}	24.36^{c}	14.08^{d}	19.60^{bc}	20.43^{bc}	16.85^{b}	17.40^{c}	15.08^{b}	15.99^{a}	18.73^{b}
3	17.72^{b}	17.06^{d}	17.16^{cd}	17.03^{c}	18.59^{c}	16.17^{b}	19.86^{c}	13.59^{b}	18.45^{a}	18.39^{b}
4	32.70^{a}	37.49^{a}	28.04^{a}	26.34^{a}	30.23^{a}	19.05^{b}	27.90^{b}	20.74^{ab}	21.64^{a}	18.93^{b}
5	34.94^{a}	26.11^{b}	21.23^{bc}	24.34^{ab}	25.86^{ab}	36.55^{a}	38.27^{a}	23.40^{a}	22.66^{a}	31.82^{a}
6	33.10^{a}	32.32^{ab}	24.16^{ab}	24.68^{c}	27.51^{ab}					
Ave.	26.44 $_{A}$	26.56 $_{A}$	19.97 $_{A}$	21.78 $_{A}$	23.49 $_{A}$	21.85 $_{A}$	23.82 $_{A}$	17.28 $_{A}$	19.18 $_{A}$	21.23 $_{A}$

Picking times	Furrow Irrigation					
	Irrigation treatments (2010)			Irrigation treatments (2011)		
	FI_{PRD50}	FI_{A50}	FI_{100}	FI_{PRD50}	FI_{A50}	FI_{100}
1	24.55^{bc}	20.49^{bc}	21.55^{bc}	16.94^{c}	23.83^{b}	22.42^{ab}
2	23.37^{bc}	22.41^{abc}	14.74^{b}	14.47^{c}	13.02^{c}	15.84^{c}
3	18.54^{c}	18.46^{c}	14.02^{b}	18.04^{bc}	16.48^{bc}	16.36^{bc}
4	33.91^{a}	28.62^{a}	28.47^{a}	22.82^{b}	22.25^{b}	19.97^{abc}
5	31.65^{ab}	29.24^{a}	29.41^{a}	38.29^{a}	32.55^{a}	25.26 ^{a}
6	33.81^{a}	26.49^{ab}	29.77^{a}			
Ave.	27.64$_{A}$	24.82 $_{A}$	22.99 $_{A}$	22.11 $_{A}$	21.62 $_{A}$	19.97 $_{A}$

Both two years were evaluated separately. Each irrigation treatment was compared according to own picking times and differences between picking times were shown as lowercase letters. For each year, averages of irrigation treatments were compared and shown as uppercase letters (P<0.05)

In terms of total carotenoid contents, in both years, there were tendency to increase after first picking period. According to both year values, total carotenoid contents were the lowest for DI_{100} and the highest for DI_{FPRD50} treated peppers. Total carotenoid contents of processing red peppers grown by furrow irrigation in 2010, for first and sixth picking period, were determined between 20.49-24.55 mg 100 g^{-1} and 26.49-33.81 mg 100 g^{-1}, respectively. The differences between picking periods were significant for each furrow irrigation treatments (*P<0.05*). At the same way, the differences between mean of picking periods were also significant when compared all the furrow irrigation treatments together (*P<0.05*). By the way, the results obtained for 2011 year, which ranged between 16.94-23.83 mg 100 g^{-1} and 25.26-38.29 mg 100 g^{-1} for first and fifth picking periods, respectively. Similarly, like drip irrigation treatments, in terms of total carotenoid contents, there were tendency to increase after first picking period in both years. The results showed that picking periods for each furrow irrigation treatments were statically significant (*P<0.05*). However, differences between means of picking periods were not significant in 2011 for processing red peppers irrigated by furrow treatments. According to both year values, total carotenoid contents were the lowest for FI_{100} and the highest for FI_{PRD50} treated processing red peppers. As a conclusion, it can be said that the processing red peppers treated with furrow irrigation accumulated higher carotenoid compounds than treated with drip irrigation.

The carotenoid content in processing red peppers varies from 0.1 to 3.2 g 100 g^{-1} dry weight with marked difference in composition. The synthesis of carotenoid pigments takes place specially during ripening of the processing red pepper, giving the different varieties a final characteristic color. Levels of carotenoid may be affected by maturity, genotype, processing (Lee et al., 1995), and picking time (Reverte et al., 2000). Abellán-Palazón et al. (2001) reported that mean carotenoid contents of 4470 and 3698 mg kg^{-1} in the Spanish and Hungarian pepper cultivars, respectively.

The carotenoid content of red Almuden peppers used in this study (433 mg kg^{-1} f.w.) was slightly lower than those described above because of the seeds, which are largely devoid of pigments (Schweiggert et al., 2007). Similar results were reported by Deli et al. (1996) for carotenoid composition in the fruits of *Capsicum annuum* cultivar Szentesi Kosszarvú during ripening.

Total Dry Matter Contents

Effects of drip and furrow irrigation treatments and picking periods on total dry matter contents (g 100 g^{-1}) of processing red peppers obtained in years of 2010 and 2011 were shown in Table 4. According to results, total dry matter of the processing red peppers obtained in 2010 with drip irrigation treatments, which ranged between 9.23-11.09 g 100 g^{-1} for first picking period and 11.23-13.24 g 100 g^{-1} for sixth picking period. It is clear that total dry matter processing red peppers is increasing with picking period. Effect of picking period on total dry matter of processing red peppers was determined significant for each drip irrigation treatments (*P<0.05*). Further, effect of different drip irrigation treatments on total dry matter of the processing red peppers was determined significant (P<0.05). Total dry matter contents ranged between 9.63-10.39 g 100 g^{-1} for first picking period and 9.03-11.42 g 100 g^{-1} for fifth picking period of the processing red peppers obtained in 2011 by the drip irrigation treatments. Effect of picking period on total dry matter of processing red peppers was determined insignificant for each drip irrigation treatments. Further, effect of different drip irrigation treatments on total dry madder of the processing red peppers was also determined insignificant. Consequently, while the lowest total dry content was obtained in the processing red peppers irrigated by DI_{100} treatment, the highest was obtained by irrigation of DI_{FPRD50} treatment.

Table 4. Total dry matters of processing red peppers according to different irrigation treatments and years (mg 100 g^{-1})

Picking times	Drip Irrigation									
	Irrigation treatments (2010)					Irrigation treatments (2011)				
	DI_{PRD50}	DI_{FPRD50}	DI_{100}	DI_{75}	DI_{50}	DI_{PRD50}	DI_{FPRD50}	DI_{100}	DI_{75}	DI_{50}
1	9.82^{c}	10.76^{c}	9.23^{b}	10.35^{a}	11.09^{a}	9.81^{a}	10.20^{a}	9.63^{a}	10.06^{a}	10.39^{a}
2	9.93 ^{c}	11.19^{c}	9.54^{b}	10.14^{a}	11.22^{a}	8.57^{a}	9.86^{a}	9.27^{a}	8.47^{a}	8.39^{a}
3	11.00^{bc}	11.26c	9.53^{b}	9.75^{a}	10.88^{a}	9.72^{a}	10.07^{a}	8.29^{a}	8.61^{a}	9.47^{a}
4	12.06^{ab}	11.57^{bc}	11.54^{a}	10.54^{a}	11.44^{a}	9.87^{a}	11.02^{a}	10.13^{a}	10.54 ^{a}	11.83^{a}
5	13.10^{a}	12.93^{a}	11.18^{a}	10.99^{a}	11.77^{a}	10.82^{a}	11.42^{a}	9.03^{a}	9.77^{a}	11.10^{a}
6	13.24^{a}	12.59^{ab}	11.61^{a}	11.23 ^{a}	11.87^{a}					
Ave.	11.52 $_{A}$	11.71 $_{A}$	10.44 $_{B}$	10.50 $_{B}$	11.38 $_{A}$	9.76 $_{A}$	10.51$_{A}$	9.27 $_{A}$	9.49 $_{A}$	10.24 $_{A}$

Picking times	Furrow Irrigation					
	Irrigation treatments (2010)			Irrigation treatments (2011)		
	FI_{PRD50}	FI_{A50}	FI_{100}	FI_{PRD50}	FI_{A50}	FI_{100}
1	10.98 ^{a}	11.10 ^{a}	10.40 ^{a}	9.98 ^{a}	9.67 ^{a}	9.93 ^{a}
2	11.46 ^{a}	11.75 ^{a}	9.79 ^{a}	9.50 ^{a}	9.79 ^{a}	9.00 ^{a}
3	12.13 ^{a}	11.72 ^{a}	10.79 ^{a}	9.54 ^{a}	11.61 ^{a}	9.40 ^{a}
4	10.92 ^{a}	11.64 ^{a}	10.68 ^{a}	10.45 ^{a}	10.69 ^{a}	9.71 ^{a}
5	11.90 ^{a}	11.49 ^{a}	10.78 ^{a}	10.75 ^{a}	10.23 ^{a}	9.33 ^{a}
6	12.25 ^{a}	12.35 ^{a}	11.46 ^{a}			
Ave.	11.60 $_{A}$	11.68 $_{A}$	10.65 $_{A}$	10.04 $_{A}$	10.40 $_{A}$	9.48 $_{A}$

Both two years were evaluated separately. Each irrigation treatment was compared according to own picking times and differences between picking times were shown as lowercase letters. For each year, averages of irrigation treatments were compared and shown as uppercase letters (P <0.05)

Total dry matter of the processing red peppers obtained in 2010 with furrow irrigation treatments, which ranged between 10.40-11.10 g 100 g^{-1} for first picking period and 11.46-12.35 g 100 g^{-1} for sixth picking period. Effect of picking period on total dry matter of processing red peppers was determined insignificant for each furrow irrigation treatments. And also, effect of different furrow irrigation treatments on total dry matter of the processing red peppers was not significant. Total dry matter contents ranged between 9.67-9.93 g 100 g^{-1} for first picking period and 9.33-10.75 g 100 g^{-1} for fifth picking period of the processing red peppers obtained in 2011 by the furrow irrigation treatments. Effect of picking period on total dry matter of processing red peppers was determined insignificant for each furrow irrigation treatments. Further, effect of different furrow irrigation treatments on total dry matter of the processing red peppers was also not significant. According to both years total dry matter results, the lowest total dry content was obtained in the processing red peppers irrigated by FI_{100} treatment, but the highest was obtained by FI_{A50} irrigation treatment.

Kırnak et al. (2016) reported that the effects of irrigation treatments on dry matter contents of bell peppers were insignificant. While the highest dry matter content was observed as 16.3%, that value ranged between 15.2-16.3% for different irrigated levels of bell peppers. Kuşcu et al. (2016) also studied soluble solid contents of red peppers for different irrigation levels. They reported that soluble solid contents ranged between 6.7-9.1% and effects of irrigation levels had significant impact on accumulation of soluble solids in red pepper.

Vitamin C Contents and Yields

Effects of drip and furrow irrigation treatments on vitamin C contents and yields of processing red peppers obtained in years of 2010 and 2011 were shown in Table 5. Vitamin C contents of processing red peppers treated with drip irrigation in 2010 and 2011 ranged between 52.4-55.1 mg 100 g^{-1} and 55.5-59.4 mg 100 g^{-1}, respectively. Vitamin C contents in processing red peppers irrigated with furrow treatments ranged between 50.1-51.2 mg 100 g^{-1} and 55.48-59.41 mg 100 g^{-1} for 2010 and 2011 crops, respectively. Effect of different irrigation treatments on vitamin C content was determined insignificant (*P>0.05*) for processing red peppers with exception of furrow irrigated processing red peppers in 2011 (*P<0.05*). Many pre-harvest and postharvest factors influence the vitamin C content of horticultural crops.

Table 5. Vitamin C contents and total yield of processing red peppers according to different irrigation levels and years

Irrigation systems	Irrigation treatments	Vitamin C (mg 100g^{-1})		Yield (kg ha^{-1})	
		2010	2011	2010	2011
Drip	DI_{PRD50}	55.0 $^{n.s.}$	54.32 $^{n.s.}$	36.75 ^{c}	40.33 ^{b}
	DI_{FPRD50}	52.4 $^{n.s.}$	52.77 $^{n.s.}$	34.16 ^{d}	33.76 ^{d}
	DI_{100}	55.1 $^{n.s.}$	54.75 $^{n.s.}$	44.17^{a}	47.79 ^{a}
	DI_{75}	56.0 $^{n.s.}$	54.90 $^{n.s.}$	40.83 ^{b}	47.17 ^{a}
	DI_{50}	55.0 $^{n.s.}$	55.68 $^{n.s.}$	34.92 ^{d}	35.97 ^{c}
Furrow	FI_{PRD50}	50.1 $^{n.s.}$	59.11 ^{a}	34.94 ^{a}	30.74 ^{b}
	FI_{A50}	51.2 $^{n.s.}$	55.48 ^{b}	31.72 ^{b}	29.32 ^{b}
	FI_{100}	50.2 $^{n.s.}$	59.41 ^{a}	35.59 ^{a}	41.50 ^{a}

The largest yield in the drip irrigation was obtained from the DI_{100} plot followed by DI_{75}, DI_{50} and DI_{FPRD50} treatments. The total yield and quality parameters were also significantly affected by the irrigation systems and water deficit for processing red pepper. Furrow irrigation treatments produced lower processing red pepper yields than drip irrigation ones. The largest yield in the drip irrigation was obtained from the DI_{100} plot followed by DI_{75}, DI_{50} and DI_{FPRD50} treatments. Although DI_{PRD50}, DI_{FPRD50} and DI_{50} received the same amount of water, DI_{PRD50} resulted in a larger yield. In furrow treatments, FI_{100} resulted in the highest yield, followed by FI_{PRD50}. Minimum yield was obtained from FI_{A50} plots, Vitamin C is the most important water-soluble antioxidant, so the consumer expectations are high vitamin C content in fruits and vegetables (Agcam et al., 2016). Large genotypic variation, preharvest factors include climatic conditions and cultural practices are responsible for the wide variation in vitamin C content of fruits and vegetables at harvest (Weston and Barth 1997). Maturity at harvest, harvesting method, and postharvest handling conditions also affect the vitamin C content of fruits and vegetable (Kader, 1988). In a study on different levels irrigated bell peppers, vitamin C content also investigated. According to results vitamin C content ranged between 1404.1-2408.1 mg kg^{-1} and no significant effect determined for different irrigation levels (Kırnak et al., 2016).Add results and findings here. Add results and findings here. Add results and findings here. Add results and findings here. Add results and findings here. Add results and findings here. Add results and findings here. Add results and findings here. Add results and findings here. Add results and findings here. Add results and findings here.

Conclusion

The processing red peppers obtained by different drip irrigation treatments and picking periods (in 2010 and 2011) showed differences by terms of color (L, a, b). Generally, L values in first year were lower than second year; a values of processing red peppers irrigated with drip treatments was higher in second year and also processing red peppers irrigated with furrow treatments had resemble a values; and finally, b values were higher in second year crops for drip and furrow treatments.

Total carotenoid contents increased after first picking for both years. The carotenoid contents of the processing red peppers obtained in first year were determined higher than first for both irrigation techniques. According to results of total carotenoid content in drip irrigated processing red peppers, the lowest result was obtained with DI_{100} treatment, while the highest was obtained with DI_{FPRD50}. Meanwhile, the total carotenoid results of processing red peppers irrigated with furrow treatments showed that the lowest and highest contents were determined in crops irrigated with FI_{100} and $FI_{PRD5}0$, respectively. As a conclusion, total carotenoid contents of furrow irrigated crops were higher than drip irrigated crops. DI_{100} irrigated processing red peppers had lowest dry matter, for both years, while DI_{FPRD50} irrigated had highest. In addition, dry matter of processing red peppers obtained by furrow irrigation, determined the lowest value for FI_{100} and highest value for FI_{A50}.

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