GOÜ. Ziraat Fakültesi Dergisi, 2009, 26(2), 63-70

Effects of Different Emitter Spaces and Irrigation Levels on Yield and Yield Components of Processing Tomato*

Aynur Özbahçe **Ali Fuat Tarı**
Soil and Water Resources Research Institute, PO 48, Konya

Abstract: This study was carried out in order to determine the effects of different emitter spaces and water stress on total fruits yield (TFY); yield suitable for processing (PFY) and paste output (PO) of processing tomato (*Lycopersicon esculentum* Mill cv. Shasta) and some quality characteristics (mean fruit weight-MFW, fruit diameter-FD, penetration value of fruit-PV, pH, total soluble solids-TSS and ascorbic acid-AA contents) under ecological conditions of Konya Plain in 2004 and 2005 years. The randomized split block experimental design with three replications was applied in the study. Drip irrigation laterals were arranged in such a way that every row had one lateral. Emitter spacing of 25, 50 and 75 cm (A, B and C respectively) were the main treatments while four levels of water supply irrigation at 7 days intervals with water amount enough to fill the soil depth of 0-60 cm till field capacity (I_1), and 25, 50 and 75% decreased water supply levels (I_2, I_3 and I_4) were applied as sub treatments of the experiment. According to results of the main treatments for two years showed that the highest total fruits yield (51.75-52.43 t ha^{-1}), as well as yield suitable for processing (47.23-49.33 t ha^{-1}) were obtained from A treatment ($p<0.01$). On the other hand, the highest TFY, PFY and PO of the sub treatments were obtained from I_1 application. MFW, FD and TSS were significantly affected from the sub treatments ($p<0.05$). High stress resulted in the highest soluble solids. Total irrigation water amount and water consumptive use of the treatment A were determined as 250-376 mm and 414-425 mm, in 2004-2005. Total irrigation water amount and water consumptive use of I_1 treatments were 426-587 mm and 520-623 mm for two years, respectively.
Key Words: emitter space, irrigation level, processing tomato, yield, quality

Farklı Damlatıcı Aralıklarının ve Sulama Düzeylerinin Salçalık Domatesin Verim ve Kalite Bileşenleri Üzerine Etkisi

Özet: Bu çalışma, 2004-2005 (2 yıl) yılları arasında, Konya ekolojik koşullarında salçalık domatesin (*Lycopersicon esculentum* Mill cv. Shasta) toplam meyve verimi (TFY), salçalık meyve verimi (PFY), salça verimi (PO) ve bazı kalite kriterleri (ortalama meyve ağırlığı-MFW, meyve çapı-FD, meyve delinme direnci-PV, pH, toplam suda çözünebilir katı madde-TSS ve askorbik asit içeriği-AA) üzerine farklı damlatıcı aralığı ve su stresinin etkisini araştırmak amacı ile yürütülmüştür. Deneme Tesadüf Bloklarında Bölünmüş Parseller Deneme Deseni'nde ve 3 tekerrürlü olarak kurulmuştur. Lateraller her bitki sırasına bir lateral olacak şekilde yerleştirilmiştir. Denemenin ana konuları 3 farklı damlatıcı aralığı 25 cm, 50 cm ve 75 cm (A,B ve C koşulları) şeklinde oluşturulurken; alt konuları da 4 farklı sulama suyu; I_1= (tam sulanan) 0-60 cm'deki eksik nemin 7 günde bir tarla kapasitesine tamamlanması, I_2= %25 kısıntı, I_3= %50 kısıntı ve I_4= %75 olacak şekilde kısıntı konularından oluşturulmuştur. İki yıllık deneme sonuçlarına göre; her iki yılda da ana konuların en iyi toplam meyve verimi (51.8.-52.4 t ha^{-1}) ve salçalık meyve verimi (47.2-49.3 t ha^{-1}) A konusundan elde edilmiştir ($p<0.01$). Diğer taraftan, alt konularda en yüksek TFY (66.2-66.8 t ha^{-1}), PFY (60.7-63.7 t ha^{-1}) ve PO (11.4-12.4 t ha^{-1}) I_1 konusundan elde edilmiştir. MFW, FD ve TSS uygulamalardan etkilenmiştir ($p<0.05$). Yüksek stress koşullarında suda çözünebilir katı madde içeriği artmıştır. Deneme yıllarında, A konusunun sulama suyu miktarı sırasıyla 250-376 mm ve su tüketim miktarı 414-425 mm olmuştur. Alt konulardan I_1 konusunun sulama suyu mikarı ise 426-587 mm iken su tüketimi 520-623 mm'dir.
Anahtar kelimeler: damlatıcı aralığı,sulama düzeyi, salçalık domates, verim, kalite

1. Introduction

Drip irrigation is quite different from the previously conventional irrigation systems. The wetted soil area may be considerably less than the full extent of the crop root zone, thus less irrigation water is needed compared with other irrigation methods. Since the wetted soil volume is relatively small, so this must be refilled more frequently. So, drip irrigation is one of the best techniques to use applying water to vegetables.

Approximately 1/3 of the total vegetable produced in Turkey is tomato, and almost half of tomatoes in the country are produced for the

* This article is a part of the research project (KHGM-03220F01) carried out by the authors from 2004 to 2005 in Soil and Water Resources Research Institute of Konya, Turkey.

purposes of processing industry. The total tomato production in Konya region is 223.837 tons (Anonymous 2008). Water research studies in Konya clearly showed severe depletion of groundwater. Therefore, recently, use of drip irrigation for tomatoes in the region has rapidly increased due to both increasing in yield of tomatoes by using drip irrigation and subsidizing of drip irrigation systems by government. In drip irrigation planning for vegetable crops, a lateral line should be establish for each crop row if the crop row spacing is wider than the dripper spacing along the lateral line (Yıldırım 1996).

Some researchers have shown that higher tomatoes yields and increased water use efficiency has been very often attributed to drip irrigation than the conventional irrigation methods. Oweis et al. (1988) determined a quadratic relationship between total yield and transpiration for drip-irrigated tomatoes. A maximum yield of about 158 t/ha could be produced with 600 mm of net irrigation. Weekly crop-pan coefficients (Kpc) were derived using transpiration data observed and Ep data from the site. Sanders *et al*. (1989) determined that yields of red fruit and all fruit increased with increasing drip irrigation rate; concentrations of soluble solids (SS) and total solids (TS) decreased with increasing irrigation rates, while fruit colour, size, and acidity increased, as did the yield of SS and TS per ha. Tekinel et al. (1989) compared drip irrigation and conventional irrigation methods for tomatoes in the Çukurova region and obtained the highest and water use efficiency (WUE) with drip irrigation. Jadhaw et al. (1990) tested drip and furrow methods for tomatoes. Tomatoes yields were 48 t ha^{-1} for drip irrigation systems with pressure-compensating emitters and 32 t ha^{-1} when furrow irrigation was used. The drip system showed a 31% saving in irrigation water. The water saved was available to irrigate a further 0.4 ha. Keller and Bliesner (1990) presented and demonstrated equations for computing the wetted area as a percentage of the total crop area for a range of crop geometry and lateral layouts based on the dimensions of the spacing between emitters and lines. May (1993) carried out a research under properly controlled moisture stress through irrigation management during fruit development and ripening of processing tomatoes, which results in maximum yield of raw products and paste. Main plot treatments of the experiment were water applications at 20, 40, and 60% depletion in the top four feet of soil while the sub-plots were the dates of last irrigation application (20, 40, and 60 days before harvest). Low stress resulted in maximum yield of raw product, and best viscosity, but resulted in low soluble solids. High stress resulted in the lowest yields, highest soluble solids, and poorest viscosity. Intermediate stress resulted in some yield loss, but, substantially improved soluble solids with good viscosity. Branthome et al. (1994) investigated processing tomato plants drip-irrigated at 0.7, 1.0 or 1.3 ETM and fertigated with 60, 120 or 180 kg N/ha. Yield and fruit weight were highest at 1.0 ETm, but higher amounts of quality components (acidity, colour and total soluble solids content (TSS)) were determined in the conditions of 0.7 ETM. Tan (1995) compared tomatoes grown on a sandy loamy soil that were either irrigated by a drip or sprinkler system or not irrigated at all. In general, drip irrigation resulted in higher fruit yields than did sprinkler irrigation. Irrigation for maximum yield was found to reduce SS of processing tomatoes (Hanson *et al.* 1997). Yohannes and Tadesse (1998) examined the effects of drip and furrow irrigation systems and plant spacing (35, 50 and 70 cm) on yield of tomato and water use efficiency (WUE) on clay loam soil. Higher yields of tomato, fruit size and WUE were obtained with drip irrigation compared to furrow irrigation. Balçın and Güleç (1998) found out no significant differences in the effect of different (0.75, 1.00 and 1.25) k_{pc} coefficients applied to furrow irrigated bush tomato. Thus, the treatment irrigated at 7-day intervals, with 0.75 k_{pc} and providing the highest yield of 92.7 t ha^{-1} under 487 mm irrigation water was recommended. pH and ascorbic acid content was not significantly affected from treatments. Candido et al. (2000) carried out an experiment with the aim of evaluating the influence of different irrigation regimes on yield and quality characteristics of processing tomato. In this research, four irrigation levels, i.e. unirrigated control, and 100%, 66%, 50% and 33% of ET_c were applied. The highest marketable yields were obtained under conditions of 100% of ET_c application, while the highest dry matter content (6.1%) was determined under conditions of rain fed treatment. Çetin et al. (2002a) conducted an experiment aiming to investigate the irrigation scheduling for drip-irrigated tomatoes using Class A pan evaporation. Irrigation water was determined as a certain ratio of Class A pan evaporation (k_{pc} = 0.50, 0.75, 1.00, and 1.25) applied at different irrigation intervals (2, 4, and 6 days). As a result of the experiment, it was determined that the maximum marketable fruit yield was obtainable under conditions of 1.00 k_{pc} applied. There are not significant among difference different irrigation intervals. Yield, fruit weight and fruit diameter were highest at 1.0 Kpc, but quality components (pH and ascorbic acid) had not significant differences.

This study was especially carried out to determine effect of emitter space on yield and yield components because there are wide range of emitter space used in our region. In such a way that, region's the farmers used to use emitter space of 25-33 cm in every kind of soil. On the other hand, according to result of infiltration test done in the experimental site, the most appropriate emitter space is 50 cm. This value is calculated from an ampric equalition (taken into consideration discharge of emitters and infiltration rate). Considering emitter test results in the experiment area, emitter space should be around 75-80 cm in respect of results of emitter tests in that place. Therefore, this study was compared to three different emitter spaces. Furthermore, this study was also to evaluate whether limited irrigation water affected yield and yield components of processing tomato.

2. Material and Methods

2.1. Experimental site

This experiment was conducted on the fields of Soil and Water Resources Research Institute in Konya, in 2004 and 2005. The experimental site is located at latitude of $37^0 52'$ N and longitude of $32^0 30'$ E, with prevailing terrestrial climate type. Recorded precipitation amounts and evaporation values in the experimental years were 99.5-28.3 and 1004.3-1094.7 mm, respectively, during growing season (from May to September). Mean temperatures were 19.9 and 20.8 ^oC in the same periods of the both years, respectively.

The soils of experimental site have a clay texture. Some of the physical and chemical properties of the experimental soil are summarised in Table 1. Properties of irrigation water using at the experiment were also showed in Table 2. Irrigation water was classified in C_2S_1 class according to the USSL classification.

Table 1. Basic physical and chemical properties of the soil at the experimental site

Soil layers (cm)	pH	ECx10^{-3} (dS m^{-1})	Organic matter (%)	Field capacity (%)	Wilting point (%)	Bulk Density (g cm^{-3})	Texture	Infiltration rate (mm h^{-1})
0-30	7.9	0.74	1.49	28.71	19.54	1.39	C	11
30-60	7.9	0.68	0.89	27.12	19.41	1.61	C	
60-90	8.0	0.62	0.60	28.71	21.34	1.61	C	

Table 2. Properties of irrigation water used in the experiments

pH	EC dSm^{-1}	Cations (me/l)				Anions (me/l)				Top	SAR
		Na	K	Ca	Mg	CO_3	HCO_3	Cl	SO_4		
7.60	0.580	0.29	0.01	2.13	3.39	0.0	4.39	0.55	0.88	5.82	0.17

2.2. Irrigation System

The drip system used in the experiment consisted of PE laterals with diameter of 16 mm, laid out along each tomatoes rows. Each plot had a PE manifold pipeline 50 mm in diameter. In-line pressure controlled drippers of 4 l/h discharge at 1.5 atm operating pressure, were spaced at distance of 25, 50 or 75 cm (depending the treatment) along the lateral. The control unit of the irrigation system had a fertilizer tank, screen-mesh filters and pressure gauges.

2.3. Irrigation Water Amount Estimation

In accordance with experimental procedure irrigation applications were done at seven days intervals (Oweist et al. 1988, Balçın and Güleç 1998, Çetin et al. 2002a). Irrigation water amount required to fill the 0-60 cm soil depth to field capacity was applied to the treatments without any reductions (I_1), and 25, 50 and 75%

decreased water supply was provided to I_2, I_3 and I_4 subplots, respectively. Canopy cover measurements were taken on 5 labelled plants prior to each irrigation application and irrigation water amount was adjusted using the determined averaged canopy cover percentage. The least canopy cover value used for adjustment in water amount was 30%, applied during the early weeks following planting. Irrigation duration was determined dividing the total irrigation amount to the number and total discharge of the drippers in the plot. Moisture soil water content was observed by gravimetric method. Before neck filling total of 70 mm irrigation water was applied as transplanting water at two or three times in both 2004 and 2005. After neck filling, water applications according to the experimental procedure were performed. We assumed that there is not deep leakage for completing field capacity deficit moisture in soil.

2.4. Irrigation Treatments

The field experiments were conducted in the experimental design of split plots in randomized blocks with three replications. Irrigation treatments are showed in Table 3. The main factor treatments consisted of three emitter spaces (ES) (A= 25 cm, B= 50 cm and C= 75 cm). The second factor tested (i.e. treatments in the split plots) was different irrigation levels (IL) applied at 7-days intervals with depleted water from field capacity (0-60 cm) (I_1), and 25, 50 and 75% reductions (I_2, I_3 and I_4).

Table 3. Treatments applied for the experiment

Main plots (emitter space)	Subplots (irrigation level)
A= 25 cm	I_1= (full irrigation)
B= 50 cm	I_2= 75 % of I_1
C= 75 cm	I_3= 50 % of I_1
	I_4= 25 % of I_1

The seedlings were planted at 1,40 m (row with) × 0.25 m spacing on May, 21 and 17, respectively in the first and second experimental years (Özbahçe 2003). Plot dimensions were 6 m × 8.4 m (50.40 m^2) in planting. One row in each sides was not taken in harvest, four rows were taken in the middle, 0.50 m parts of the beginning and end of the plots were not harvested. Plot dimensions were 5.6 m x 5.0 m (28 m^2) in the harvest. There are a lateral in each rows and 6 plant rows in per plot. Total parcels are 36 numbers ((3 × 4) x 3). The distance among blocks among was 3 m and the distance among plots among are 1.4 m.

2.5. Agricultural Applications

Seedlings of Shasta variety (*Lycopersicon esculentum* cv. Shasta F_1) were supplied by TAT Canned Company (Bursa-Turkey). Water applications according to treatments were carried out between 1 July-9 September in 2004 and 23 June-1 September in 2005. Yield harvesting were made 4 times in each year.

Totally, 160 kg N ha^{-1} and 75 l/ha phosphoric acid (85%) fertilizers were applied during the growing season. Part of the fertilizers, 2/4 and 2/5 for phosphorous and nitrogen respectively were applied with irrigation water in the first fertilization, and the remainder parts were supplied during the growing period, using the irrigation system.

2.6. Calculated Parameters

Total fruit yield (TFY) was reckoned from total of both matured and immature fruits in the last harvest and total of the other harvests. Fruit yield suitable for processing (PFY) was calculated from only matured fruits of the whole of harvest. Paste output (PO) (28 brix) was calculated from the total yield per hectare and TSS (total soluble solids) values.

Some quality characteristics of fruits were investigated during the second harvest. Mean fruit weight (MFW-g), fruit diameter (FD-mm, with a compass at the middle of fruit) and penetration value of fruit (PV-kg/cm^2, by the hand penetrometer) determined on thirty fruits, randomly collected as subsamples from the each plot for quality assessment. Then, fruits were homogenized in a blender and portions of the homogenate were taken to determine the pH (determined by the pH-meter), total soluble solids (TSS) (%, determined by tusing a refract meter) and ascorbic acid content (AA) (mg/100 g). Ascorbic acid content was measured by classical titration method using 2,6-dichlorophenol indophenol solution.

2.7. Statistical Evaluation

Data related to fruit yield suitable for processing, paste output and quality components obtained from the experiment were subjected to an analysis of variance using the procedure given by Yurtsever (1984), and Duncan Mean Separation Test procedure was applied. In order to compare the experimental years, experimental data subjected to an ANOVA test, and year x treatment interactions were evaluated.

Evapotranspiration (ET) from each plot was determined using the soil water balance equation. Water use efficiency and irrigation water use efficiency under various regimes of water supply was determined using the equation given by Howell et al. (1990).

WUE = (Ey/ET), IWUE= (Ey/I), where, WUE= Water use efficiency (kgha^{-1} mm), WUE= Irrigation water use efficiency (kgha^{-1} mm), Ey= Yield (kgha^{-1}), I= applied water amount (mm), ET= Seasonal water consumption (mm).

3. Results and Discussion

3.1. Some Quality Characteristics of Processing Tomato

The effects of emitter space on some quality characteristics of processing tomato are summarized in Table 4. Considering the statistical evaluation, there were significant ($p<0.05$) effects of the different emitter spaces on MFW, FD and TSS whereas of the different irrigation levels on MFW, FD, PV and TSS values in both experimental years.

Table 4. Quality characteristics of processing tomato in response to different emitter space and irrigation levels

The main plots	MFW (g)*		FD (mm)*		PV (kg/cm^2)^{ns}		pH^{ns}		TSS (%)*		AA (mg/100 g)^{ns}	
ES	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
A	45.32a	46.62 a	41.26a	41.76a	1.25	1.24	4.21	4.32	5.73b	5.96c	17.27	17.74
B	43.65a	44.61ab	40.12b	40.78b	1.18	1.18	4.20	4.30	6.29a	6.56b	17.62	17.77
C	41.56b	41.90 b	39.09c	38.45c	1.16	1.15	4.19	4.26	6.30a	6.87a	17.50	17.58
The subplots	MFW (g)*		FD (mm)*		PV (kg/cm^2)		pH^{ns}		TSS (%)*		AA (mg/100 g)^{ns}	
IL	2004	2005	2004	2005	2004*	2005*	2004	2005	2004	2005	2004	2005
I_1	50.64a	52.30a	43.04a	42.47a	1.25a	1.22a	4.18	4.29	5.28c	5.54c	17.57	17.98
I_2	44.92b	46.51b	40.79a	41.39a	1.19b	1.20a	4.21	4.28	5.55c	6.34b	17.12	17.35
I_3	43.17bc	43.31bc	38.89ab	39.59a	1.17b	1.18a	4.25	4.30	6.43b	6.74b	17.42	17.78
I_4	35.31c	35.39c	37.89b	37.87b	1.15b	1.15b	4.17	4.30	7.15a	7.12a	17.73	17.69

$^{*}p<0.05$ ^{ns}non-significant

MFW and FD were significantly ($p<0.05$) affected by emitter spacing and irrigation level in both years (Table 4). The highest MFW was obtained from A and I_1 applications (45.32-46.62 g, 50.64-52.30 g) in 2004-2005, respectively. But, for the main plots, the difference between A and B treatments (43.65 g and 44.61 g, respectively) was not found significant in both years ($p<0.05$). The highest FD was obtained from the same treatments (A and I_1) (41.26-41.76 mm, 43.04-42.47 mm, respectively). Although emitter spaces had not significant effect on PV, irrigation treatments significantly affected PV. The highest PV was obtained from I_1 treatment (1.25-1.22 kg/cm^2, respectively). Both emitter space and irrigation levels ($p<0.05$) affected TSS for two years. pH and AA contents for emitter space treatments changed between 4.19-4.32 and 17.27-17.77 mg/100g for both years. Whereas the highest TSS content was obtained from C treatment (6.30-6.87%), AA was obtained from B treatment (17.62-17.77, respectively) in the main plots. The lowest TSS was obtained from A treatment (5.73-5.96%, in 2004-2005, respectively). The lowest TSS (5.28-5.54%, respectively) among the subplots was obtained from full irrigated treatment (I_1) while the highest TSS (7.15-7.12%, respectively) was obtained from the least water application treatment (I_4) (Table 4). The treatments did not significantly affect pH and AA in both years.

Similar results were obtained by Sanders et al. (1989) and Branthome et al. (1994). They determined that fruit sizes the highest for the treatments whose water requirements were supplied completely. May (1993) reported that no stress resulted in low soluble solids. High stress resulted in highest soluble solids and poorest viscosity. Furthermore, similar results were also found Hanson et al. (1997) and Candido et al. (2000). Balçın and Güleç (1998) and Çetin et al. (2002a) determined that water application treatments did not affect pH and ascorbic acid contents.

3.2. Total Fruit Yield, Fruit Yield Suitable for Processing (PFY) and Paste Output (PO)

Data related to yield suitable for processing and paste output obtained from the experiments carried out in 2004 and 2005 are presented in Table 5. Data obtained from the 2-year study showed that tomato yields (TFY, PFY and PO) was significantly ($p<0.01$) affected both emitter spaces and water supply levels.

Table 5. Total fruit yield, fruit yield suitable for processing and paste output obtained from the treatments during the experimental years (t ha^{-1})

The main plots	TFY*		PFY*		PO^{ns}		The subplots	TFY*		PFY*		PO**	
	2004	2005	2004	2005	2004	2005		2004	2005	2004	2005	2004	2005
A	51.8a	52.4a	47.2a	49.3a	9.2	10.0	I_1	66.2a	66.8a	60.7a	63.7a	11.4a	12.4a
B	49.0a	49.7a	43.5a	43.1b	9.5	9.7	I_2	55.3b	57.7b	49.8b	53.8b	9.9a	12.1a
C	43.2b	42.9b	36.6b	39.4b	7.7	9.4	I_3	42.1c	39.9c	36.4c	35.7c	8.2ab	8.5ab
							I_4	28.4d	29.0d	22.9d	22.7d	5.8b	5.8b

$^{*}p<0.01$ $^{**}p<0.05$ ^{ns}non-significant

Yields suitable for processing were obtained from A-I_1, the treatment consisting of 25 cm emitter space and irrigated at 7-day intervals with water amount enough to fill soil depth of 60 cm to field capacity. As could be concluded from data included in table 5, the highest TFY (51.8-52.4 t ha^{-1}, respectively) and PFY (47.2-49.3 t ha^{-1}, respectively) were obtained from plants growing in the plots with 25 cm emitter space (A treatment). The treatments did not significantly affect among emitter spaces in both years. According to the subplots' results, the highest TFY (66.2-66.8 t ha^{-1}), PFY (60.7-63.7 t ha^{-1}) and PO (11.4-12.4 t ha^{-1}) were obtained from fully irrigated treatment (I_1) for both years, respectively.

The results with fruit yield obtained by some researchers were similar to our results. The results obtained from the study discussed here are comparable with those published earlier. In a similar way, May (1993) found that light stress imposed to tomato resulted in maximum yield. According to a study carried out by Yrisarry et al. (1993), the total yield increased with the amount of water applied. Moreover, Balçın and Güleç (1998), reported that there were no significant differences between coefficients of k_{pc} (0.75, 1.00 and 1.25), applied to bush tomatoes irrigated by furrow method. Thus, they recommended lowest k_{pc} value for tomato irrigation, applied at 7-day intervals. In studies conducted in different parts of the world and Turkey showed that maximum marketable tomato yields are obtainable under irrigation with water amounts based on 100 % ETc (Candido et al. 2000), or irrigation at 4-day intervals with water amounts determined using k_{pc} 1.00 (Çetin et al. 2002a-b).

3.3. Irrigation Water (IWA) - Water Consumptive Amounts (WCA) and Irrigation Water Use Efficiency (IWUE) - Water Use Efficiency (WUE)

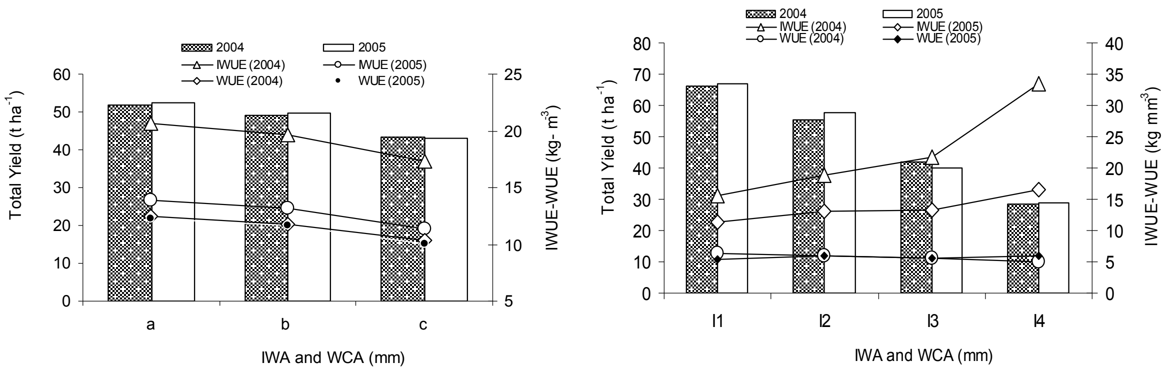
Recorded seasonal precipitation amounts for the first and second experimental years were 99.5 mm and 28.3 mm, respectively. Total of 11 irrigation applications were done during the both experimental years. Results for irrigation water amounts and water consumptive uses of tomato are summarized in Table 6. Data included in the table showed that averaged (250-376 mm) amounts of the main plots' irrigation water are applied to all treatments. The water consumptive use values of the mentioned treatments were estimated as 414 and 425 mm, respectively for 2004 and 2005. The difference of mentioned values in terms of years may be resulted from not only variations at precipitation amounts but also second year's higher dry than first year between years.

Data included in the table showed that averaged (426-587 mm) amounts of the subplots' irrigation water are applied to I_1 treatment. The water consumptive use values of the same treatment were estimated as 520 and 623 mm, respectively for 2004 and 2005 (Table 6). Irrigation water use efficiencies ranged from 11.4 to 20.7 kg m^{-3} depending on the main treatments and experimental years while the subplot treatment's IWUE ranged from 11.4 to 33.4 kg m^{-3} (Table 6).

WUE of the main and subplots were 10.1-12.5 kg m^{-3} and 9.9-12.7 kg m^{-3}, respectively. IWUEs, WUEs of the main and subplot treatments differ considerable among the treatments and generally tends to increase with a decline in irrigation (Fig. 1). The higher yield obtains also the higher IWUE and WUE. Similarly, Mbarek and Boujelben (2004) showed that IWUE was greatest with double rows in the tomatoes grown in the greenhouse. But, approximately the same value of IWUE (21.9 kg m^{-3}) was obtained. Çetin et al. (2002b) were determined that WUE was 23.8 kg m^{-3}. Howell (2006) and Yohennes and Tadesse (1998) obtained similar results.

Table 6. Irrigation Water (IWA) Amounts -Water Consumptions (WCA) and WUE-IWUE (kg- m^{-3}) of the main and subplots treatments for the two years

The main plots	IWA (mm)		WCA (mm)		IWUE		WUE	
	2004	2005			2004	2005	2004	2005
A	250	376	414	425	20.7	13.9	12.5	12.3
B	250	376	414	425	19.6	13.2	11.8	11.7
C	250	376	414	425	17.3	11.4	10.4	10.1
The subplots	IWA (mm)		WCA (mm)		IWUE		WUE	
	2004	2005			2004	2005	2004	2005
I_1	426	587	520	623	15.5	11.4	12.7	10.7
I_2	294	440	470	477	18.8	13.1	11.8	12.1
I_3	193	302	377	357	21.8	13.2	11.2	11.2
I_4	85	176	288	242	33.4	16.5	9.9	11.9



(a) (b)

Figure 1. Total yield and irrigation water use efficiency (IWUE)-water use efficiency (WUE) for each treatment and amounts of irrigation water and water consumptive applied (the main (*a)* and subplots (*b)*)

4. Conclusions

As a result of a 2-year study it was concluded that yield suitable for processing as well as past out output and some quality characteristics (MFW, FD and TSS) are strongly affected both the space between emitters and water supply levels. As a general rule; total fruit yield, yield suitable for processing and MFW, FD and PV increased with decreasing space between emitters and increasing irrigation water amounts. On the other hand, the results of the study also showed that increasing emitter space to 50 cm lead to increased paste output during the experimental years.

Results for paste output obtained from treatments with moderate emitter space of 50 cm and light reduction (% 25) in irrigation level could be used as a good basis for economically irrigation system design and reduced irrigation strategy development in regions with a serious water scarcity problem.

References

Anonymous, 2008. Agricultural Structure and Production. Government Statistic Inst. of Prime Minister Pub. (http://www.tuik.gov.tr).

Balçın, M. and Güleç, H., 1998. Irrigation scheduling of drip-irrigated tomatoes using class A pan evaporation in Tokat region (in Turkish). Soil and Water Sources Research Result Report, Tokat-Turkey.

Branthome, X.Y., Ple, J., Machado R. and Bieche, B.J. 1994. Influence of drip irrigation on the technological characteristics of processing tomatoes. Fifth International Symposium on The Processing Tomato. 23-27 Nov. 1993, Sorrento, Italy. Acta Horticulturae, No: 376, 285-290.

Candido, V., Miccolis V. and Perniola, M., 2000. Effects of irrigation regime on yield and quality of processing tomato (*Lycopersicon esculentum* Mill.) cultivars. III International Symposium on Irrigation of Horticultural Crops. Acta Hort., (ISHS) 537:779-788

Çetin, Ö., Uygan, D., Boyacı, H. and Yıldırım, O., 2002a. Effects of different irrigation treaments on yield and quality of drip-irrigated tomatoes under Eskisehir conditions (in Turkish). IV. Vegetable Agriculture Symposium. 17-20

September, Bursa-Turkey.

Çetin, Ö., Yıldırım, O., Uygan, D. and Boyacı, H., 2002b. Irrigation scheduling of drip-irrigated tomatoes using class A pan evaporation. Turk. J. Agric. For. 26: 171-178.

Hanson B.R., May D.M., and Schwankl L.J., 1997. Drip irrigation of processing tomatoes. In 'ASAE Annual International Meeting'. Minneapolis, Minnesota, USA, 10–14 August, 1997.

Howell, T.A., Cuenca, R.H. and Solomon, K.H., 1990. Crop Yield Response. Management of Farm Irrigation Systems (Ed. Hoffman et al.). ASAE, 311-312

http://www.actahort.org/books/335/335_16.htm

Howell, T.A., 2006. Challenges in increasing water use efficiency in irrigated agriculture. In: The proceedings of International Symposium on Water and land Management For Sustainable Irrigated Agriculture, April 4-8, 2006, Adana-Turkey.

Jadhaw, S.S., Gutal, G.B. and Chougule, A.A., 1990. Cost economies of the drip irrigation system for tomatoes crop. Department of Agricultural Engineering, College of Agriculture, Pune, India.

Keller, J. and Bliesner, R.D., 1990. Sprinkle and trickle irrigation (Chapman and Hall: New York).

May, D.M., 1993. Moisture stress to maximize processing tomato yield and fruit quality. International Symposium on Irrigation of Horticultural Crops. 1 April1993. http://www.actahort.org/books/335/335_67.htm

Mbarek, K.B. and Bouljelben, A., 2004. Behavior of tomato (*Lycopersicon esculentum* Mill) and red pepper (*Capsicum annum* L.) crops under greenhouse conditions conducted in single and twin rows. Tropicultura 22 (3), 97-103.

Oweis, T.Y., Shatanawi, M.R. and Ghavi, I.O., 1988. Optimal irrigation management for protected tomato in the Jordan Valley. Dirasat: Human and Social Sciences 15, 104-118.

Özbahçe, A., 2003. The problems of processing tomato agriculture and the solution proposals. Agriculture Associations Union in Turkey. Pub.No: 141, Ankara.

Sanders, D.C., Howell, T.A., Hile, M.M.S., Hodges, L., Meek, D. and Phene, C.J., 1989. Yield and quality of processing tomatoes in response to irrigation rate and schedule. Journal of the American Society for Horticultural Science 114, 904–908.

Tan, C.S., 1995. Effect of drip and sprinkler irrigation on yield and quality of five tomatoes cultivars in Southeastern Ontario. Canadian Journal of Plant Science, 1995, 75: 1, 225-230.

Tekinel, O., Kanber, R., Önder, S., Baytorun, N. and Baştuğ, R., 1989. The effects of trickle and conventional irrigation meyhods on some crop yields and water use efficiency under Çukurova conditions. Irrigation: Theory and practice (edited by Rydzewski, J.R. and Ward, C.F.J. 1989) 641-651, Southampton, UK.

Yıldırım, O., 1996. Irrigation Techniques of Horticultural Crops (in Turkish). Ankara University, Agricultural Faculty, Publication Number 1438/420, p.188.

Yıldırım, O., 2003. Design of irrigation systems (in Turkish). Ankara University, Agricultural Faculty, Publication No: 11536/489, Ankara-Turkey.

Yohannes, F. and Tadesse, T., 1998. Effect of drip and furrow irrigation and plant spacing on yield of tomato at Dire Dawa, Ethiopia. Agricultural Water Management, Volume 35, Issue 3, 201-207.

Yrisarry, B.J.J., Losada, P.M.H. and Podriguez, A.R., 1993. Response of processing tomato to three different levels of water and nitrogen applications. International Symposium on Irrigation of Horticultural Crops. 1 April 1993.

Yurtsever, N., 1984. Experimental Statistics Methods (in Turkish). Republic of Turkey, Ministry of Agriculture The Former General Directorate of Rural Service, Soil-Fertilizer Research Inst. Pub. No: 121, Techniques Pub. No: 56, Ankara-Turkey.