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The Effects of Plastic Mulched Drip Irrigation on Yield, Fruit Quality and Water Productivity of Table Tomatoes

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Abstract
This study examined the effects of different irrigation levels and plastic mulching on table tomatoes (*Lycopersicon esculentum* Mill., *cv. Zahide*) yield, fruit quality, and water productivity. A field experiment was conducted in western Turkey during the summer seasons of 2017 and 2018 at the Application and Research Station, University of Bilecik Seyh Edebali. The research was designed as a split-plot design with three replications. The main plots consisted of two mulch applications (mulch (M) and no mulch (NM)), and sub-plots were consisting of four drip irrigation levels (100% (IL100), 75% (IL75), 50% (IL50), and 25% (IL25) of the evaporation measured in the Class A Pan). IL100 treatment with mulch application obtained the highest marketable yields as 72.56 t ha^{-1} in 2017 and 75.50 ha^{-1} in 2018. Increasing irrigation water amounts decreased total soluble solids (TSS), total sugar, titratable acidity, and lycopene values. Fruit yield and fruit weight values were increased with increasing irrigation water amounts. The highest water productivity values were obtained from interaction IL25 × M in both years. Mulching increased water productivity, especially with an effect on plant water consumption. Therefore, for drip irrigation under plastic mulch, the IL100 irrigation level can be recommended under conditions where water resources are sufficient, and IL75 is recommended when insufficient.

Keywords Evapotranspiration · Irrigation levels · Lycopene · Total soluble solids

Introduction

With the rapid increase of the world population, the demand for water and food is increasing, but on the contrary, freshwater reserves have started to decrease. This problem will bring not only a water shortage but also a food shortage. Because the reduction of water allocated to agriculture means a decrease in plant yield. Therefore, a contradiction must be resolved between the global increase in food demand and available water resources. For this reason, water resources should be protected and used rationally.

The work described has not been published before; that it is not under consideration for publication anywhere else; that its publication has been approved by all co-authors.

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Regarding water resources, agriculture is the largest water user, with 70%, so agricultural water management has become more critical (Rosegrant et al. 2009). However, the irregular rainfall regime, the increase in urban life, and the developing industry's need for water will make it necessary to limit the amount of water for the agriculture sector. Therefore, it has become necessary to use existing soil and the water resources allocated to agriculture with the highest possible efficiency (Shtull-Trauring et al. 2022). In recent years, the general approach in irrigated agriculture has begun to be based on obtaining more products with less water or not experiencing product loss. Different water-saving methods are used, and deficit irrigation is the most used method.

Deficit irrigation gives the plant more minor of the water it needs. The general approach of deficit irrigation is to save water and increase water productivity in different growth periods depending on the sensitivity of the plant to water or throughout the whole growing season without causing a significant decrease in plant yield (Geerts and Raes 2009). In addition, product diversity can be increased by opening new areas to irrigation with deficit irrigation (Romero et al. 2022).

Table 1 Some properties of the experiment area soil

Depth (cm)	Texture	Field capacity (%)	Bulk density ($g\,cm^{-3}$)	pH	Organic matter (%)	Phosphorus P_2O_5 ($kg\,ha^{-1}$)	Potassium K_2O ($kg\,ha^{-1}$)
0–30	Clay Loam	27.87	1.26	7.77	1.18	267.4	1162.8
30–60	Loam	24.57	1.21	7.81	1.24	274.5	915.9
60–90	Loam	26.67	1.27	7.71	2.07	210.2	964.2

Besides deficit irrigation, mulch application can also increase water use efficiency by reducing the evaporation on the soil surface. Mulching preserves soil moisture and reduces water evaporation by 10–50% (Swiader et al. 1992; Zhang et al. 2018). With mulch application, more products can be obtained, and thus both an increase in income and a reduction in a significant part of the input cost can be achieved (Ekinci and Dursun 2006). Many researchers have scientifically emphasized that mulching in vegetable cultivation has positive effects on crop yield, earliness, and fruit quality (Ekinci and Dursun 2006; Lushi et al. 2012; Mochiah et al. 2012; Kosterna 2014; Mu et al. 2014; Zhang et al. 2017, 2018).

Tomato and tomato products are rich in vitamins A and C, lycopene,-carotene, lutein, lectin, various organic acids, flavonoids, and phenolic compounds. Cholesterol-free tomato is also rich in folate, potassium, fiber, and protein (Fawad and Khan 2022). In addition to its nutritional properties, tomato is an important commercial product integrated into the agricultural industry. As well as fresh consumption, it is consumed as a processed food product with different uses and is used as the raw material of these products. These are fruit and vegetable canned food, tomato paste, fruit juice, frozen, dried vegetable and fruit industry, and other branches of industry. This variety of usage areas increases the importance of tomatoes (Heuvelink 2018).

Before deficit irrigation, the plant's reaction to being grown to water constraints and the water savings to be obtained should be at the forefront. Tomato is a plant that irrigates farming and its high water demand; because of that, it is an essential plant in terms of how it will react to deficit irrigation and the water savings to be provided. Also, tomato is the most grown vegetable globally and in Turkey. Therefore, increasing water productivity in tomato plants is vital in saving water. Many irrigation studies have shown that to obtain high yields and quality, the seasonal water requirement of tomatoes ranges from 400 to 700 mm (Hanson and May 2006; Salokhe et al. 2005; Mukherjee et al. 2010).

Previous studies reported different irrigation levels on tomatoes for different ecological conditions. However, studies investigating the effects of mulching and different irrigation levels on table tomatoes are limited. Further studies are needed to determine the effects of table tomatoes on yield, quality, and water productivity for a different climates, soil, and new genotypes. Our study determined the effects of mulch application and different irrigation water levels on table tomatoes' yield, quality, and water productivity under the drip irrigation method.

Materials and Methods

Experimental Site

Field studies were carried out in the Application and Research Station (40° 6′ N, 30°.0′ E, 500 m a.s.l.) at the University of Bilecik Seyh Edebali, in the province of Bilecik, Turkey. The experimental region has a semi-arid climate according to the Thornthwaite classification. Based on long-year meteorological data, the average temperature in the Bilecik is 12.5 °C, and the annual average rainfall is 450 mm. The total rainfall was 94.7 mm in 2017 and 116.3 mm during the tomato growing season in 2018.

Some properties of the study soils are shown in Table 1, and it has a clay-loam soil texture in 0–30 cm soil depth.

Experimental Design and Treatments

During the 2017 and 2018 growing seasons, open field experiments were conducted using a split-plot randomized complete block design with mulch application (mulch (M) and no mulch (NM)) as main plots and different irrigation levels (100% (IL100), 75% (IL75), 50% (IL50), and 25% (IL25) of the evaporation measured in the Class A Pan) as subplots. Three replicates and the four sub-plot treatments were randomly allocated in each main plot. Sub-plots were 6 m by 3.2 m with four rows. Black polyethylene nylon was used as the mulch material.

The irrigation water applied in irrigation treatments was determined by the equations given below (Allen et al. 1998).

$$ETo = Epan \times kp \quad (1)$$

$$ETc = ETo \times kc \quad (2)$$

where *ETc* is crop evapotranspiration (ET) of tomato (mm day^{-1}), *ETo* is reference crop ET (mm day^{-1}), *kc* is crop coefficient, *kp* is pan coefficient (0.25, 0.50, 0.75, and 1.00 for treatments of IL25, IL50, IL75, and IL100, respectively), and *Epan* is evaporation from Class A Pan (mm day^{-1}). The *kc* coefficient was taken differently according to the development periods; it was taken 0.60 for the initial period, between 0.60–1.15 in the crop development period, 1.15 in the mid-season period, and 1.15–0.80 in the late-season period (Allen et al. 1998).

The calculated amount of irrigation water was applied at 5-day intervals, and the water was applied to the subplots via a drip irrigation system. The laterals were installed in each row (0.8 m apart) at 0.1 m away from the plant row. The dripper lines had inline compensating emitter pressure, and the discharge rate of the emitters was 2.0 L h^{-1} at an operating pressure of 1 bar. The emitter spacing was chosen as 0.20 m based on the soil characteristics. The water pumped from underground was filtered through a 150-mesh screen. The system was established in the plots before the tomato seedlings were transplanted into the experimental plots.

Tomato Agronomy

This study was conducted with Zahide F1, a popular table tomato (*Lycopersicon esculentum* Mill.) in the Bilecik province. The tomato seedlings were transplanted on May 20th for both years. The row spacing was 0.8 m, and the plant-plant spacing was 0.4 m. Plant density was 31,250 plants per hectare. Weed control was carried out three times during the season by hand hoeing in the plots without mulch. According to the recommendations based on soil analysis, a total of 120 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1}, and 20 kg K_2O ha^{-1} were applied in the form of urea, triple superphosphate, and K_2SO_4, respectively. Mature (completely red) tomatoes were harvested. Final harvests were made at the end of September in both years.

Measurements

The soil moisture contents at 0–30, 30–60, and 60–90 cm depth below the dripper were monitored by gravimetric sampling. The dry-and-weight method measured soil moisture content every ten days in both years during the growing season.

Marketable fruit yield was calculated as a ton of fruit weight per hectare. Ten fruits randomly selected from each subplot were sampled to determine the quality characteristics. Single fruit weight was determined by taking the average weight of the sampled tomatoes. A hand refractometer (Hanna HI96801) was used to determine total soluble solids content (°Brix). Contents of total sugar and lycopene were determined using Agilent 1100 series high-performance liquid chromatography. Titratable acidity was calculated according to the titrimetric method as the percentage of citric acid in the juice.

Evapotranspiration and Water Productivity

Tomato evapotranspiration was calculated using a water balance equation (Shen et al. 2019).

$$ETa = I + P + W \pm \Delta S - D - R \quad (3)$$

where I is the irrigation amount (mm), P is the seasonal amount of precipitation (mm), W is the groundwater flow into the root zone (mm), ΔS is the change in soil moisture content (mm), D is the drainage (mm), and R is the surface runoff. Precipitation values were supplied from Bilecik State Meteorology Station. W was ignored as the groundwater level was 15 m below the ground surface, which was not deep enough to affect the growth of table tomatoes. The terrain of the experimental area was flat, and precipitation was not heavy, so runoff and drainage were also negligible.

Water Productivity

Irrigation water productivity (IWP, kg m^{-3}) and water productivity (WP, kg m^{-3}) were estimated by the following equations (Pereira et al. 2012):

$$IWP = \frac{FY}{I} \quad (4)$$

$$WP = \frac{FY}{ETa} \quad (5)$$

where FY is the marketable fruit yield (kg ha^{-1}), I is the volume of seasonal irrigation water applied (m^3 ha^{-1}), and ETa is the actual seasonal evapotranspiration (m^3 ha^{-1}).

Statistical Analysis

Yield and quality parameters were subjected to analysis of variance (ANOVA) using Minitab 18 software. The significance of irrigation and mulch applications was determined using the F test. When the F-test was significant, the Tukey test ($P < 0.05$) was used to compare group means of irrigation and mulching treatments and their interactions.

Results and Discussion

Irrigation Water and Evapotranspiration

All subplots received the same level (30 mm) of irrigation during the establishment period (10 days after transplanting). The irrigation application, according to the treatments, was started in June and continued five days intervals. Table 2 shows data on applied irrigation water amounts and

Table 2 Irrigation water applied (IWA) and actual seasonal evapotranspiration (ETa) in two years experiment

Years	Irrigation level (IL)	IWA (mm)		ETa (mm)		Percentage change of the ETa (%)
		Mulch	No Mulch	Mulch	No Mulch	
2017	*IL25*	162	162	190	247	23.1
	IL50	279	279	298	326	8.6
	IL75	395	395	375	488	23.2
	IL100	512	512	482	570	15.4
2018	*IL25*	155	155	183	268	31.7
	IL50	265	265	265	350	24.3
	IL75	374	374	381	510	25.3
	IL100	484	484	486	593	18.0

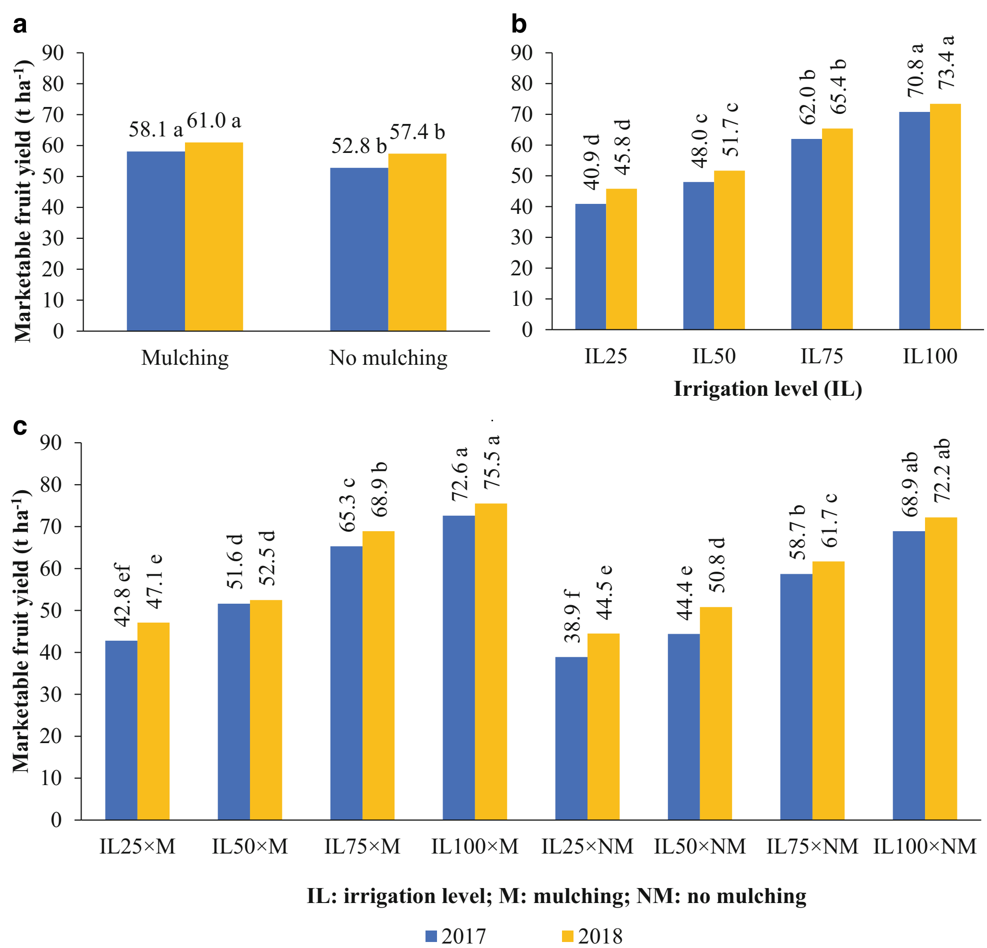


Fig. 1 Marketable fruit yield of table tomatoes

measured evapotranspiration for 2017 and 2018. The irrigation water applied ranged from 162 to 512 mm in 2017 and 155 to 484 mm in 2018. The seasonal ETa ranged from 190 to 570 mm in 2017 and 183 to 593 mm in 2018. The highest ETa was obtained from IL100 treatment, and the lowest was obtained from IL25. Similar results were obtained in both years, and lower ETa values were obtained in mulch plots at all drip irrigation water levels. These results show that plant water consumption decreases with plastic mulch application (Table 2).

Fruit Yield

Figure 1 shows the effects of different irrigation levels and plastic mulching on the marketable fruit yield of table tomatoes. As shown in Fig. 1a, mulched plots obtained higher yields than plots without mulch, and the difference between them was statistically significant in both years. The difference between irrigation levels was also statistically significant (Fig. 1b). In the first year of the study, the average fruit yield varied between 40.9–70.8 t ha^{-1} and between 45.8–73.4 t ha^{-1} in the second year. In both years, the highest fruit yield was obtained from treatment IL100, and the lowest was obtained from IL25. According to the irrigation level × mulching interaction, the marketable fruit yield ranged from 38.9 t ha^{-1} to 72.6 t ha^{-1} in 2017 and from 44.5 t ha^{-1} to 75.5 t ha^{-1} in 2018 (Fig. 1c). In both years, the highest yield was obtained in the IL100 × M interaction, followed by IL100 × NM. It was determined that the yield values decreased with the decrease in the irrigation level in both mulch and no mulch conditions. Thus, the lowest yield was obtained from the IL25 treatment. The results showed that the highest marketable yield could obtain using full irrigation and mulch application in both years. Most similar studies showed that the fruit yield was significantly increased with increasing the amount of irrigation water, and they emphasized that the highest fruit yields were obtained from full irrigation and mulch application (Patanè et al. 2011; Ertek et al. 2012; Singh and Kamal 2012; Biswas et al. 2015; Zhang et al. 2018; Aliabadi et al. 2019).

Fruit Quality

The effect of mulch application on fruit weight was statistically significant ($P<0.01$), and higher fruit weight values were determined from mulch treatments in both years (Table 3). The effect of drip irrigation levels on fruit weight was statistically significant ($P<0.01$). In both years, the highest fruit weight values were obtained from the IL100 treatment, and while lowest were determined from the IL25. Fruit weight increased with increasing irrigation level and mulch application. Fruit weights varied between 109.06–75.13 g in 2017 and 121.97–80.82 g in 2018. The highest fruit weight was obtained from the IL_{100} × M interaction as 109.06 g in 2017 and 121.97 g in 2018. The lowest fruit weight was obtained from IL_{25} × NM interaction in both years, but no significant difference was found between IL_{25} × M interactions. Several researchers reported that fruit weight increases with increased irrigation levels and mulch application (Aruna et al. 2007; Singh et al. 2009; Samaila et al. 2011; Rajablariani et al. 2012).

It was determined that the effect of mulch application on total soluble solids was statistically significant, and higher TSS values were observed in no mulch plots in both years (Table 3). In the first year of the experiment, the average TSS was obtained as 7.01 for mulched plots, and it was obtained as 7.19 for no mulch plots; in the second year, 6.88 for mulch plots and 7.09 for no mulch plots. The effect of irrigation levels on the TSS was statistically significant. In 2007, the TSS average varied between 6.52 and 7.51 °Brix, and in 2008, between 6.45 and 7.45 °Brix. In both years of the study, the highest TSS values were obtained from IL25 treatments and the lowest from IL100. TSS var-

Table 3 Fruit quality parameters of table tomatoes

Treatments	Fruit weight (g)		Total soluble solids (°Brix)		Total sugar (g 100 g^{-1})		Titratable acidity (g 100 ml^{-1})		Lycopene [a] (mg kg^{-1})
Mulching	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2018**
Mulch (M)	91.53 a	101.15 a	7.01 b	6.88 b	2.59	2.46 b	0.325 b	0.321b	94.21 a
No mulch (NM)	87.40 b	94.09 b	7.19 a	7.09 a	2.64	2.80 a	0.340 a	0.354 a	91.25 b
F-value	*6.07**	*25.47***	*5.87**	*32.38***	2.52^{ns}	*86.92***	*10.57***	*42.25***	*8.52**
Irrigation level (IL)									
IL100	107.28 a	114.56 a	6.52 c	6.45 d	1.96 d	1.96 d	0.293 b	0.315 c	85.43 c
Il75	93.40 b	102.29 b	7.07 b	6.90 c	2.54 c	2.49 c	0.313 b	0.320 c	86.07 c
IL50	81.55 c	91.84 c	7.30 ab	7.14 b	2.87 b	2.82 b	0.345 a	0.353 b	92.21 b
IL25	75.63 d	81.80 d	7.51 a	7.45 a	3.10 a	3.25 a	0.380 a	0.363 a	107.23 a
F-value	*69.58***	*100.96***	*33.06***	*126.81***	*292.75***	*217.12***	*64.40***	*22.17***	*99.69***
Interaction									
M × IL100	109.06 a	121.97 a	6.70 de	6.32 e	1.94 f	1.97 f	0.290	0.300	85.14 d
M × IL75	96.48 bc	105.12 b	6.90 cd	6.90 cd	2.52 c	2.25 e	0.305	0.305	87.05 cd
M × IL50	84.45 de	94.73 cd	7.08 bcd	7.06 bc	2.86 b	2.63 d	0.335	0.335	92.85 c
M × IL25	76.12 e	82.78 e	7.35 abc	7.23 b	3.05 ab	2.97 bc	0.370	0.345	111.82 a
NM × IL100	105.50 ab	107.14 b	6.33 e	6.57 de	1.98 d	1.94 f	0.296	0.330	85.71 cd
NM × IL75	90.32 cd	99.45 bc	7.23 abc	6.90 cd	2.56 c	2.73 cd	0.320	0.335	85.08 d
NM × IL50	78.64 e	88.95 de	7.52 ab	7.22 bc	2.87 b	3.01 b	0.355	0.370	91.57 cd
NM × IL25	75.13 e	80.82 e	7.66 a	7.66 a	3.14 a	3.53 a	0.390	0.380	102.64 b
F-value	*69.58***	*100.96***	*6.17***	*5.79***	9.33^{*}	12.76^{**}	0.44^{ns}	0.08^{ns}	*4.44**

*: Significant at the P < 0.05, **: Significant at the P < 0.01, *ns*: Not significant, *a,b,c,....*: Tukey groups

[a] Lycopene values were measured in 2018 only

ied with irrigation level and mulch application. The highest TSS was obtained from IL25 × NM interaction in both years. The lowest TSS yield was obtained from IL_{100} × NM interaction in 2017 and IL_{100} × M interaction in 2018. Similar results have been obtained in other studies. They concluded that TSS increased as irrigation decreased (Patanè and Cosentino 2010; Kuşçu et al. 2014a; Lahoz et al. 2016; Tarı and Sapmaz 2017; Aliabadi et al. 2019).

The effect of mulch application on total sugar was statistically insignificant in the first year and statistically significant ($P < 0.01$) in the second year (Table 3). In the first year of the experiment, the average total sugar was obtained as 2.59 g 100 g^{-1} for mulched plots, 2.64 g 100 g^{-1} for no mulch plots; in the second year, 2.46 g 100 g^{-1} for mulch plots, and 2.80 g 100 g^{-1} g for no mulch plots. The effect of irrigation levels on the total sugar was statistically significant. In the first year of the study, the average total sugar value varied between 1.96–3.10 g 100 g^{-1}, and in the second year, between 1.96–3.25 g 100 g^{-1}. In both years of the study, the highest values were obtained from the treatment IL25, and the lowest was obtained from the IL100. The effect of mulching and irrigation interaction on total sugar was statistically significant in both experimental years. The highest total sugar content was obtained in the IL_{25} × NM interaction in both years, while the lowest was obtained from IL_{100} × M interaction in 2017 and IL_{100} × NM interaction in 2018. In some other studies, researchers obtained similar results. They concluded that total sugar content decreased with increasing irrigation water (Patanè et al. 2011; Kuşçu et al. 2014a).

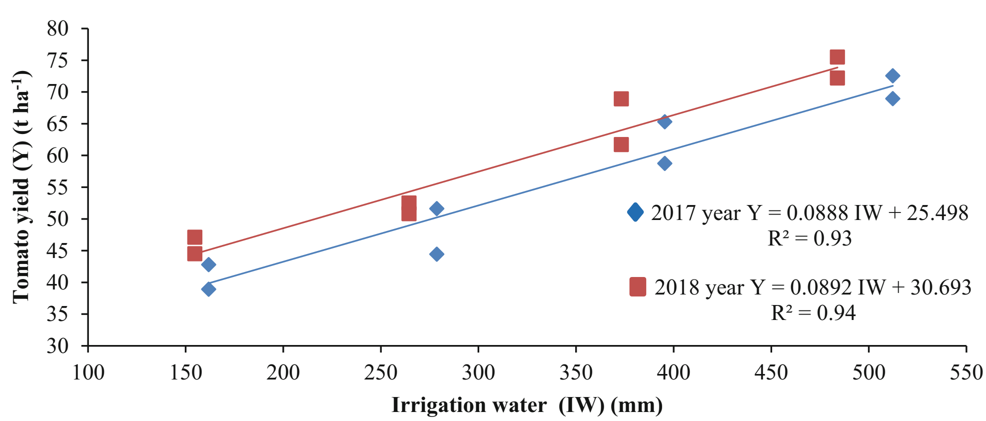
It was determined that the effect of mulch application on titratable acidity was statistically significant in both years of the study (Table 3). In the first year of the study, the titratable acidity average was obtained as 0.325 g 100 ml^{-1} for mulch plots, 0.340 g 100 ml^{-1} in no mulch plots, in the second year, 0.321 g 100 ml^{-1} for mulch plots, and 0.354 g 100 ml^{-1} in no mulch plots. The effect of irrigation levels on titratable acidity was statistically significant ($P < 0.01$). In the first year of the study, the average titratable acidity varied between 0.293–0.380 g 100 ml^{-1} and in the second year between 0.315–0.363 g 100 ml^{-1}. In both years, the highest titratable acidity was obtained from IL25 plots, and the lowest titratable acidity was obtained from IL75 plots. According to the interaction of mulching × irrigation level, the highest titratable acidity value was obtained from the IL_{25} × NM interaction, while the lowest was obtained from IL_{100} × M interaction in both years. Researchers emphasized that titratable acidity decreased with increasing irrigation levels (Aruna et al. 2007; Patanè et al. 2011; Kuşçu et al. 2014a; Aliabadi et al. 2019).

The effect of irrigation water level and mulch application on lycopene content was statistically significant (Table 3). Higher lycopene content was obtained in mulched plots. The average lycopene value was 94.21 mg kg^{-1} for mulch plots and 91.25 mg kg^{-1} for no mulch plots. The highest lycopene content was obtained from IL25 plots, while the lowest was obtained from IL100. When we look at the irrigation × mulching interaction effect on lycopene value, it varied from 111.82 to 85.08 in mg kg^{-1} in 2018. The highest lycopene values were obtained in the IL_{25} × M interaction as 111.820 mg kg^{-1}. The lowest lycopene values were obtained in the IL_{75} × NM interaction at 85.08 mg kg^{-1}. Lahoz et al. (2016) obtained similar results and the highest lycopene content of 199.52 mg kg^{-1} from 0.75 E pan. Kuşçu et al. (2014b) obtained the highest lycopene content from 0.50 E pan. In line with the findings of this study, they reported that the lycopene content increased with decreasing the irrigation level.

Water-yield Relationship

Irrigation water-yield and crop evapotranspiration-yield functions are given in Figs. 2 and 3, respectively. A linear relationship was found between marketable fruit yield and irrigation water at a 99% confidence level. Linear regression equations were obtained between applied irrigation water (IW) and marketable fruit yield (Y) as Y = 0.0888 IW + 25.498 (R^2 = 0.93) in 2017 and Y = 0.0892 IW + 30.693 (R^2 = 0.94) in 2018 (Fig. 2). Linear regression equations were obtained between crop evapotranspiration

Fig. 2 The relationships between marketable fruit yield and seasonal irrigation water



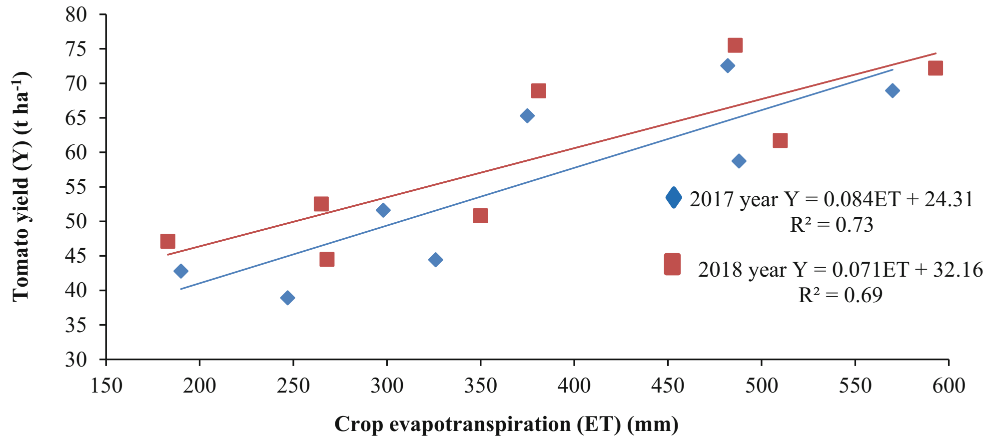


Fig. 3 The relationships between marketable fruit yield and seasonal evapotranspiration

Table 4 Irrigation water productivity (IWP) and water productivity (WP) values in two years of experiment

Irrigation level (IL)	Mulching	IWP kg m^{-3}		WP kg m^{-3}	
		2017	2018	2017	2018
IL25	*Mulch*	26.6 a	30.6 a	22.5 a	25.7 a
	No mulch	24.2 b	28.9 b	15.7 c	16.6 d
IL50	*Mulch*	18.6 c	19.9 c	17.3 b	19.8 b
	No mulch	15.9 d	19.3 c d	13.6 d	14.5 f
IL75	*Mulch*	16.5 d	18.5 d	17.4 b	18.1 c
	No mulch	14.9 d e	16.6 e	12.0 e	12.1 g
IL100	*Mulch*	14.2 e	15.6 f	15.0 c	15.5 e
	No mulch	13.5 e	14.9 f	12.1 e	12.2 g

Values at columns followed by different letters are significantly different at the 0.05 level

(ET) and marketable fruit yield (Y) as Y = 0.084 ET + 24.31 (R^2 = 0.73) in 2017 and Y = 0.071 ET + 32.161 (R^2 = 0.69) in 2018 (Fig. 3). The linear relationship between applied irrigation water and tomato yield shows that the yield increases linearly depending on the amount of water applied per unit.

Water Productivity

WP and IWP are essential indicators for the evaluation of irrigation practices. The IWP and WP values are given in Table 4. The values differed depending on the irrigation water levels. The lowest WP values were obtained from IL75 and IL100, with no mulch plots, while the highest was obtained from IL25 × M in both years. The highest IWP value was obtained from IL25 × M at 26.6 kg m^{-3} in 2017 and 30.6 kg m^{-3} from IL25 × M in 2018. The lowest IWP values were obtained from IL100 with no mulch plots. According to the two-year results, WP and IWP values increased with the irrigation level decreased. This result shows that the WP and IWP values can increase with certain irrigation application restrictions. Thus, it may be appropriate to reduce irrigation water in regions where it is scarce. Mulch application also increased the WP and IWP values at all irrigation water levels. This result shows that higher WP can be obtained with mulch application besides water restriction. In other studies, the researchers obtained similar results. They reported that the WP and IWP values increased with the water shortage and mulch application (Mukherjee et al. 2010; Kuscu et al. 2014b; Biswas et al. 2015; Agbna et al. 2017).

Conclusion

This study examined the effects of plastic mulching and different irrigation levels on crop water evapotranspiration, water productivity, yield, and some quality characteristics of table tomatoes grown under ecological conditions of Bilecik province in Turkey. Mulching increased water productivity, especially with an effect on plant water consumption. In addition, the effect of mulching on yield and some quality parameters was found to be positive. Single fruit weight and yield increased with the increase in irrigation level, whereas total soluble solids, titratable acidity, total sugar, and lycopene values in tomato fruits decreased. Considering all the results, the effect of mulch application and irrigation levels on marketable fruit yield and some quality parameters in the study general was statistically significant. The use of mulch was better at all irrigation water levels, and an average of 18% to 25% lower plant water consumption values was obtained in both years compared to plots without mulch. As a result, we need to get more efficiency from the unit area and use water effectively so that mulch application can be preferred because of increased fruit yield and water productivity. In terms of yield, there are no significant differences statistically between IL75 × M, IL100 × NM interactions at a 5% significance level, so that the IL75 × M interaction can be suggested instead of IL100 × NM interaction. Thus, high water productivity can be achieved, and some quality properties will be improved without a significant yield loss. Finally, IL100 irrigation level can be recommended under conditions where water resources are sufficient, and IL75 is recommended when insufficient. This study's results can be considered, especially in table tomato cultivation in semi-arid climatic regions.

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Conflict of interest M. Karaer, H.T. Gültaş and H. Kuşçu declare that they have no competing interests.

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