Investigation of Sunburn in Watermelon Cultivars with Different Ground Color Under Irrigation and Rainfed Conditions

Veysel ARAS*
Alata Horticultural Research Institute, Mersin, Türkiye
***Correspondence: varas2001@yahoo.com**

Abstract

Because of the increase in global warming, farmers have started to experience significant global production losses in watermelon as in many products. A research using striped watermelon, ungrafted Crimson Tide grafted on Nun9075 and Paskal hybrid cultivars with dark green ground color, ungrafted and grafted on Gürdal, was conducted in 2018 and 2019 to research sunburn in watermelon in the open field. It was determined as the harvest time when the atria and leeches were dry. At harvest time, samples were taken and stored. Following these dates, one half of the experiment received irrigation, while the other half rainfed and continued for an additional month. Harvests were made in each plot a month later and the sunburn rates in each plot were assessed using the 1–5 scale we developed. The Paskal variety, whose bark ground color was black in both years, had the sunburn start earlier, and after one month, there were almost no marketable fruits on the plants left in the field with both watery and rainfed applications. The burn scale rates is high in ungrafted cultivars, but increases in unirrigated cultivars. There was not much difference between the grafted and ungrafted varieties in terms of SSC and TA (%). It is recommended to use grafted seedlings and to continue irrigation in places where sunburn may occur. However, creating favorable conditions for strong vine growth that shades the watermelon fruit is the greatest way to avoid sunburn damage.

Key words: Watermelon, grafting, irrigated, rainfed, postharvest, sunburn.

1. Introduction

One of the most economically significant members of the Cucurbitaceae family is the watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai). World watermelon production is 101.6 million tons. China is the largest producer with 60.0 million tons of watermelon production. Türkiye is the second largest watermelon producing country with 3.5 million tons. Other countries that produce the most watermelon are India, Iran, Algeria, Brazil and USA respectively (FAOSTAT, 2020).

Sunburn-related products experience global production losses (Bertelsen et al., 1994; Liu et al., 2001; Felicetti and Schrader et al, 2009; Baameur et al., 2009; Racsko and Schrader, 2012). Photodamage to the fruits of different crops grown in temperate areas as a result of excessive

heat and/or light radiation causes sunburn, a physiological disease that can be seen (visible and ultraviolet light). The main reason is thought to be an increase in the production of reactive oxygen species that cause oxidative damage due to the fruit's inability to recover from stress. Consumers may not like the distinctive morphological and structural phenotype that results from this and farmers may experience significant production losses as a result. Berries contain a wide range of defense mechanisms, including accumulation of heat shock proteins and photoprotective pigments, as well as the manufacture of antioxidants, to attenuate or minimize the generation of reactive oxygen species and deactivation of the photosynthetic apparatus (Munné-Bosch and Vincent, 2019). However, when stress factors that change fruit surface approach a particular level, these mechanisms lose their effectiveness (both duration and intensity) (Munné-Bosch and Vincent, 2019). Growers use different cultural and sunburn control techniques, such as choosing rootstocks that are less susceptible to sunburn (Wünsche et al., 2002), coating fruit with a reflecting material (Glenn et al., 2002), using shading nets (Gindaba and Wand, 2005), and evaporative cooling (Evans, 1993). Although they can reduce the likelihood of obtaining a sunburn, these cultural practices cannot entirely negate its negative effects. Sunburn is a condition that affects many different fruits and vegetables, not just one particular type or variety. Watermelon is one of these vegetables. Sunburn marks will appear on the watermelon's upper surface where sunlight is more prevalent.The upper surface of the watermelon fruit has a gray region where the skin pigment has been damaged as a result of the pigment degradation process, when the temperature on the sunny side of the fruit exceeds 41.6°C (107°F) (Maynard ve Hopkins, 1999). Cucumber and pepper fruits should be taken into consideration in conjunction with high temperatures and intense light, although the cause of sunburn in watermelon fruit is still unknown (Maynard ve Hopkins, 1999). The average watermelon peel temperature hits 41.6 °C in the sun and 36.1 °C in the shade at a time when the ambient air temperature is 31.9 °C (Maynard ve Hopkins, 1999). The easiest technique to avoid sunburn damage, though, is to create the right conditions for a sturdy base structure that can provide shade for the watermelon fruit (Maynard and Hopkins, 1999; Camen et al, 2018). Dark green and striped watermelons are more likely to get sunburned than light green and gray-green kinds (Maynard and Hopkins, 1999; Shrefler et al., 2015).

It has been observed that complaints to the Agricultural Insurance Pool Management Company (TARSIM) have increased in recent years in Türkiye due to sunburn and this study was carried out at Alata Horticultural Research Institute Türkiye in order to supported by TARSIM.

Although watermelons with mild sunburn are marketed, little is known about watermelons that are delayed for various reasons and have a lot of sunburn. Therefore, our aim was to determine the sunburn rates and to investigate the changes in fruit internal quality of watermelons of different varieties, which were grown in grafted/ungrafted and stored/irrigated/rainfed conditions from the time of harvest, in relation to the increase in the severity of sunburn browning of watermelon. This study filled this gap since there was no study in the previous literature on the effects of grafting and irrigation on sunburn after harvest time.

2. Material and Method

In the study, the study was carried out with ungrafted Crimson Tide varieties grafted on NUN9075 (*Cucurbita maxima*×*Cucurbita moschata*) and Paskal hybrid varieties grafted on Gurdal (*Cucurbita maxima*×*C.moschata*) with dark green ground color.

The experiment was carried out in field conditions belonging to Alata Horticultural Research Institute in 2018 and 2019. The seedlings of Crimson Tide variety of the ungrafted and grafted on NUN9075 were provided from Antalya Seedling Company and seedlings of the Paskal variety ungrafted and grafted on Gürdal were provided from Genetika Seed Company.

The experiment was established on April 05 in 2018 and on March 27 in 2019. Soil analysis results are given in Table 1. The seedlings were planted on April 21 in the area with coordinates 36°37'39.1"N 34°20'28.5"E in 2018 and on April 11 in the area with coordinates 36°37'35.16"N 34°20'28.51"E in 2019. The seedlings were planted with 2.5 x 0.7 m spacings and distances on the prepared banks with a width of 0.7 m and a height of 0.4 m, covered with black mulch.

Table 1. Soil analysis of used parcels.

Year	Analyzes	Limit Values	Analysis Results (0-30 cm)
2018	Texture (100 g/ml)	30-50	38.00 (loamy)
	Total Calcitic ($CaCO_3$ %)	5-15	35.40 (high calcareous)
	Salinity E.C. ds/m (25 °C)	0-0.8	0.35 (slightly salty)
	Organic matter (%)	3-4	3.30 (optimum)
	pH 1: 2,5	6.0-7.0	7.56 (slightly high)

	Available potassium (mg/kg)	244-300	350.90 (high)
	Receivable phosphorus (mg/kg)	20-40	29.80 (optimum)
2019	Texture (100 g/ml)	30-50	40.00 (loamy)
	Total Calcitic (CaCO3 %)	5-15	32.30 (high calcareous)
	Salinity E.C. ds/m (25 oC)	0-0.8	0.45 (slightly salty)
	Organic matter (%)	3-4	2.06 (defficient)
	pH 1: 2,5	6.0-7.0	7.02 (optimum)
	Available potassium (mg/kg)	244-300	647.70 (very high)
	Receivable phosphorus (mg/kg)	20-40	65.20 (high)

The experiment was established in a randomized completely block design with four replications and 20 plants in each replication. Irrigation was done with drip irrigation system. Soil analysis was carried out in the experimental area and fertilizations were given as pure substance as 14-16 kg/da N, 8-10 kg/da P_2O_5, 6-8 kg/da K_2O according to the analysis results (Güçdemir, 2012). Spraying against spider mites and other pests was done as soon as they were seen. Weed control was done mechanically and manually.

The normal harvest time of the fruits was determined as 09 July in 2018 and 02 July in 2019, when the auricle and tendril were dry. From this stage onwards, the fruit samples of the varieties taken from the grafted and ungrafted watermelon varieties were placed in the cold storage with 4^{o}C and 95% relative humidity. In addition, half of the grafted and ungrafted watermelon plants in the field trial were irrigated and the other half unwatered and the trial was continued for one more month, starting from the harvest date. One month after harvest, the sunburn rates in each plot were determined on a 1-5 scale value (Figure 1). The weighted scale average was calculated by taking the arithmetic average of all the scale values taken separately for each application and variety of fruits.

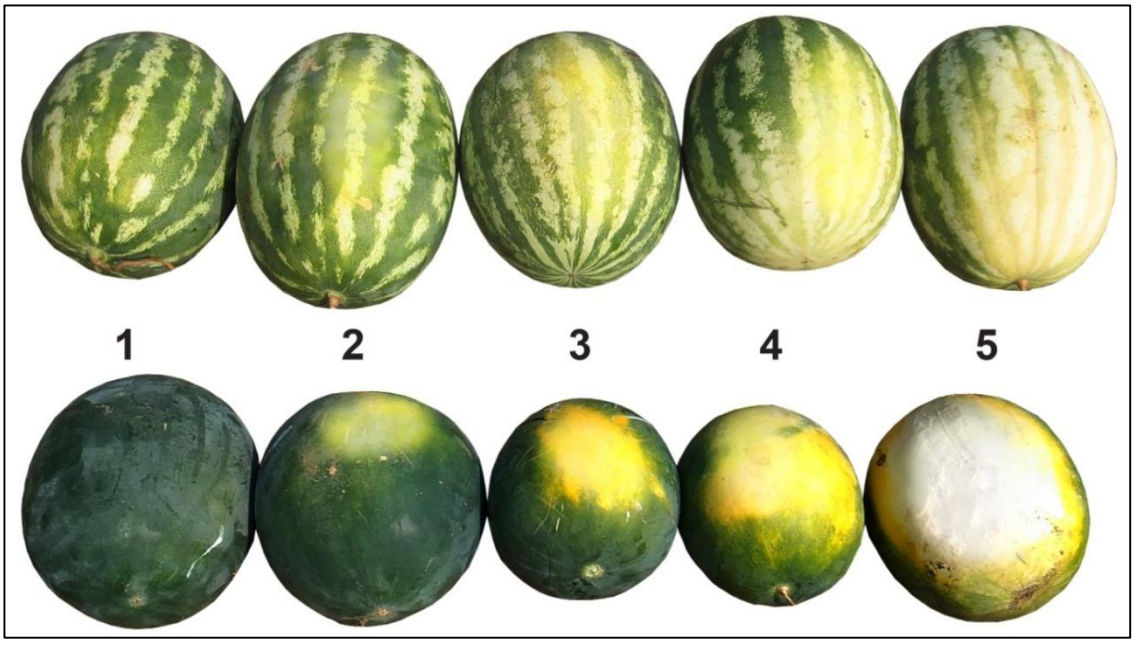

Figure 1. The scale applied for sunburn in watermelon (1: Slightly burned or not burned; 2: Slightly burned; 3: Moderately burned; 4: Burned; 5: Excessively burned).

Although sunburn is generally thought of as a disorder that only affects the appearance of the skin of a watermelon, this research shows that it also directly affects the internal quality characteristics of the fruit. Schrader et al. (2009) investigated the changes in SSC and TA, which are parameters affecting fruit core quality, in their study related to the increase in the severity of sunburn. As in this study, SSC, TA and pH values were examined as quality parameters. One month after the harvest, fruit samples were taken from the fruits in the storage at 4°C and from the ones whose scale value was 1 (slightly burned or not burned) and cultivated under irrigated and rainfed conditions in field conditions and water total soluble solid (SSC %), titratable acidity (TA %) and pH levels of these fruits were investigated. Total amount of total soluble solid [SSC] was measured by hand refractometer (Atago ATC-1E Model (Atago Co. Ltd., Tokyo, Japonya), titratable acidity [TA], a potentiometric method (5 ml of the obtained fruit juice was taken, and the acidity value was measured with the help of the 0.1 N NaOH solution], and the pH reached 8.1. These measurements have no direct effect on quality-related sunburn but were made to give an idea of the consumer acceptability of sunburn and non-sunburn.

The climate values of 2018 and 2019, when the research was conducted, are given in Table 2.

Table 2. Climatic data of the trial area.

Year	Climate Parameters	April	May	June	July	August
2018	Total global solar radiation (kWsaat/m²)	168.5	186.9	180.8	222.8	199.1
	Max. global solar radiation (watt/m²)	463 800	480 000	485 400	478 800	438 000
	Total global radiation (kWsaat/m²)	168.5	186.9	180.8	222.8	199.1
	Total sunshine duration (hour)	229.3	245.8	237.6	311.1	307.9
	Max. temperature (°C)	31.9	34.7	34.3	33.1	36.3
	Min. temperature (°C)	7.2	12.7	17.2	17.9	19.4
	Average temperature (°C)	18.1	22.9	25.4	27.8	28.3
	Max. humidity (%)	86.4	82.1	78.6	80.0	78.8
	Min. humidity (%)	41.7	39.6	51.5	66.1	61.0
	Average humidity (%)	69.7	67.3	72.3	74.3	72.4
	Precipitation (mm=kg÷m²)	6.4	0.8	2.0	3.2	4.4
2019	Total global solar radiation (kWsaat/m²)	160.3	210.6	208.9	224.8	192.8
	Max. global solar radiation (watt/m²)	454 200	493 800	501 600	502 800	459 748
	Total global radiation (kWsaat/m²)	160.3	210.6	208.9	224.8	192.8
	Total sunshine duration (hour)	230.2	314.5	313.2	339.3	323.2
	Max. temperature (°C)	28.9	35.5	32.3	32.5	34.3
	Min. temperature (°C)	5.7	9.4	15.5	18.4	18.8
	Average temperature (°C)	15.6	21.4	25.3	27.4	28.2
	Max. humidity (%)	84.4	82.6	82.1	78.8	79.7
	Min. humidity (%)	48.2	41.6	51.5	48.4	53.2
	Average humidity (%)	71.2	68.8	75.7	72.3	72.7

Precipitation (mm=kg÷m²)	21.0	6.4	0.6	0.0	0.0

2.1. Statistical analysis

Statistical evaluation of Weighted averages of the scale values for each replication were calculated using the JMP 7.0 Package program, after which the weighted average scale values underwent logarithmic transformation and the percentage values underwent angle transformation. Following the normality test, pairwise comparisons using the T-Student method and multiple (interactions) comparisons using the Tukey test were performed at the 0.05 significance level.

3. Results and Discussion

In 2018, the ungrafted Paskal watermelon cultivar under irrigated conditions had a scale 1 2.53%, a scale 2 16.35%, a scale 3 11.35%, a scale 4 34.30%, and a scale 5 it was seen that it was 35.43%. When we look at the burn rate of the ungrafted Paskal watermelon variety in the scale based on rainfed, burn rate of scale 1 was 0.0%, scale 2 was 8.98%, scale 3 was 26.93%, scale 4 was 28.85% and scale 5 was 35.15%. The burn rate of Paskal watermelon variety grafted on Gürdal in irrigated conditions, scale 1 was 4.35%, scale 2 was 20.03%, scale 3 was 40.25%, scale 4 was 27.00% and scale 5 was 8.48%. Grafted Paskal watermelon variety has a burn rate of, in the scale under rainfed conditions; scale 1 was 0.00%, scale 2 was 8.90%, scale 3 was 18.05%, scale 4 was 45.25% and scale 5 was 26.60%. The burn rate of the ungrafted Paskal watermelon variety in irrigated conditions in 2019, scale 1 was 0.00%, scale 2 was 2.35%, scale 3 was 5.45% scale 4 was 39.63% and scale 5 was 52.55%. The burn rate of the ungrafted Paskal watermelon variety under rainfed conditions, scale 1 was 0.0%, scale 2 was 2.42%, scale 3 was 12.93%, scale 4 was 37.13% and scale 5 was 47.53%. The burn rate of the grafted Paskal watermelon variety under irrigated conditions, scale 1 was 1.78%, scale 2 was 8.45%, scale 3 was 16.85%, scale 4 was 35.53% and scale 5 was 37.40%. The burn rate of the grafted Paskal watermelon variety under rainfed conditions, scale 1 was 0.0%, scale 2 was 3.53%, scale 3 was 6.28%; scale 4 was 32.05%, scale 5 was 58.13% (Table 3).

Table 3. The rates of sunburn 1 month after harvest in 2018 and 2019 in irrigated and rainfed conditions of the grafted and ungrafted Paskal variety.

Years	Grafted/Ungrafted	Irrigated/ Rainfed	Burn Scale Rates (%)				
			1	2	3	4	5
2018	Ungrafted	Irrigated	2.53	16.35	11.35	34.30	35.43
		Rainfed	0.00	8.98	26.93	28.85	35.15
	Grafted	Irrigated	4.35	20.03	40.25	27.00	8.48
		Rainfed	1.20	8.90	18.05	45.25	26.60

2019	Ungrafted	Irrigated	0.00	2.35	5.45	39.63	52.55
		Rainfed	0.00	2.42	12.93	37.13	47.53
	Grafted	Irrigated	1.78	8.45	16.85	35.53	37.40
		Rainfed	0.00	3.53	6.28	32.05	58.13

When we evaluate the combination of Paskal variety with ungrafted and grafted on Gürdal according to the weighted scale averages in 2019, it is seen that the sunburn rate of the grafted (3.51) is less affected than the ungrafted (3.87). It is also seen that continuing irrigation (3.50) after harvest reduces the rate of sunburn compared to being left rainfed (3.89). The sunburn rate of Paskal variety grafted on Gürdal rootstock grown in irrigated conditions was found to be at least (3.15). When we evaluate the combination of Paskal variety with ungrafted and grafted on Gürdal for 2019, it was observed that grafted (4.22) sunburn rate was less affected than ungrafted (4.36). It was also observed that continuing irrigation (4.20) after harvest reduced the rate of sunburn compared to being left rainfed (4.37). The sunburn rate of Paskal variety grafted on Gürdal rootstock grown in irrigated conditions was determined to be at least (3.98) (Table 4).

Table 4. Weighted Scale Averages of grafted and ungrafted Paskal variety 1 month after harvest in 2018 and 2019 under irrigated and rainfed conditions.

Years	Grafted/Ungrafted	Irrigated	Rainfed	Average
2018	Ungrafted	3.84 a	3.90 a	3.87 A
	Grafted	3.15 b	3.87 a	3.51 B
	Average	3.50 B	3.89 A	
CV (%5): 0.009				
Prob>f	Grafted/ungrafted 0.0011	Irrigated / Rainfed 0.0006	Grafted/ungrafted* Irrigated / Rainfed 0.0021	
2019	Ungrafted	4.42 a	4.30 a	4.36 A
	Grafted	3.98 b	4.45 a	4.22 B
	Average	4.20 B	4.37 A	
CV (%5):0.004				
Prob>f	Grafted/ungrafted 0.0067	Irrigated / Rainfed 0.0025	Grafted/ungrafted* Irrigated / Rainfed <.0001	

The mean values given in different capital letters in the same column and row and the mean values of the interaction in the middle of the table with lower case letters were statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

The burn rate of the ungrafted Crimson Tide watermelon variety under irrigated conditions in 2018, scale 1 was 3.60%, scale 2 was 11.48%, scale 3 was 23.00%, scale 4 was 30.95%, scale 5 was 31.05%. The burn rate of the ungrafted Crimson Tide watermelon variety under rainfed

conditions in 2018, scale 1 was 1.95%, scale 2 was 6.55%, scale 3 was 18.58%, scale 4 was 27.45%, scale 5 was 45.50%. The burn rate of the grafted Crimson Tide watermelon variety under irrigated conditions in 2018, scale 1 was 6.88%, scale 2 was 11.45%, scale 3 was 12.08%, scale 4 was 35.68%; scale 5 was 33.95%. The burn rate of the grafted Crimson Tide watermelon variety under rainfed conditions in 2018, scale 1 was 3.48%, scale 2 was 9.85%, scale 3 was 8.85%, scale 4 was 28.28, scale 1 was 49.58%. The burn rate of the ungrafted Crimson Tide watermelon variety under irrigated conditions in 2019, scale 1 was 13.03%, scale 2 was 10.98%, scale 3 was 10.25%, scale 4 was 28.83%, scale 5 was 36.90%. The burn rate of the ungrafted Crimson Tide watermelon variety under rainfed conditions in 2019, scale 1 was 3.28%, scale 2 was 3.88%, scale 3 was 10.83%, scale 4 was 31.30% and scale 1 was 50.75%. The burn rate of the grafted Crimson Tide watermelon variety under irrigated conditions in 2019, scale 1 was 24.90%, scale 2 was 17.75%, scale 3 was 17.05%, scale 4 was 23.38%, scale 1 was 16.93%. The burn rate of the grafted Crimson Tide watermelon variety under rainfed conditions in 2019, scale 1 was 10.70%, scale 2 was 11.90%, 3 was 23.58%, scale 4 was 22.55%, scale 5 was 31.30% (Table 5).

Figure 5. The rates of sunburn 1 month after harvest in 2018 and 2019 in irrigated and rainfed conditions of the grafted and ungrafted Crimson Tide variety.

Years	Grafted/Ungrafted	Irrigated/ Rainfed	Burn Scale Rates (%)				
			1	2	3	4	5
2018	Ungrafted	Irrigated	3.60	11.48	23.00	30.95	31.05
		Rainfed	1.95	6.55	18.58	27.45	45.50
	Grafted	Irrigated	6.88	11.45	12.08	35.68	33.95
		Rainfed	3.48	9.85	8.85	28.28	49.58
2019	Ungrafted	Irrigated	13.03	10.98	10.25	28.83	36.90
		Rainfed	3.28	3.88	10.83	31.30	50.75
	Grafted	Irrigated	24.90	17.75	17.05	23.38	16.93
		Rainfed	10.70	11.90	23.58	22.55	31.30

When we evaluated the combination of Crimson Tide watermelon ungrafted and grafted on NUN9075 according to the weighted scale averages in 2018, no statistical difference was found in terms of sunburn rates. Continuing to irrigate after harvest (3.76) seems to reduce the rate of sunburn compared to leaving it based on rainfed (4.09). When we evaluated the combination of the Crimson Tide variety ungrafted and grafted on NUN9075 for 2019, it is seen that grafted (3.21) sunburn rate was less affected than ungrafted (3.94). Continuing to irrigate after harvest

(3.28) seems to reduce the rate of sunburn compared to being left rainfed (3.87). The interactions in both years were insignificant (Table 6).

Figure 6. Weighted Scale Averages of grafted and ungrafted Crimson Tide variety 1 month after harvest in 2018 and 2019 under irrigated and rainfed conditions.

Years	Grafted/Ungrafted	Irrigated	Rainfed	Average
2018	Ungrafted	3.74	4.08	3.91
	Grafted	3.78	4.11	3.95
	Average	3.76 B	4.09 A	
CV (%5):0.003				
Prob>f	Grafted/ungrafted 0.3164	Irrigated / Rainfed <.0001	Grafted/ungrafted* Irrigated / Rainfed 0.8267	
2019	Ungrafted	3.66	4.22	3.94 A
	Grafted	2.90	3.52	3.21 B
	Average	3.28 B	3.87 A	
CV (%5):0.009				
Prob>f	Grafted/ungrafted <.0001	Irrigated / Rainfed <.0001	Grafted/ungrafted* Irrigated / Rainfed 0.7389	

The mean values given in different capital letters in the same column and row and the mean values of the interaction in the middle of the table with lower case letters were statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

Fruit samples were taken from grafted and ungrafted Paskal and Crimson Tide varieties from fruits in cold storage at 4°C one month after harvest and from those that continued to be grown under irrigated and rainfed conditions in field conditions and had a scale value of 1 (marketable fruits) and the amounts of SSC, TA and pH in these fruits were examined. In the Paskal variety, there was no statistically significant effect of inoculation in terms of SSC in 2018 and 2019, one month after harvest, when compared with marketable fruits in irrigated and rainfed conditions in the field and stored fruits, the highest values were obtained as 9.42% and 9.20%, respectively. In the interaction between grafted and ungrafted and marketable fruits in irrigated and rained conditions in the field and preserved fruits, the highest values taken were 10.25% and 9.70%, respectively from the preserved and ungrafted Pascal variety and the lowest values taken were 6.57% and 7.03%, respectively from the ungrafted Pascal variety in irrigated conditions (Table 7).

Table 7. SSC (%) amounts of the grafted and ungrafted Paskal variety preserved 1 month after harvest, in irrigated and rainfed conditions in the field in 2018 and 2019.

Years	**Grafted/Ungrafted**	**Preserved**	**Irrigated**	**Rainfed**	**Average**
2018	Ungrafted	10.25 a	6.57 c	7.55 bc	8.12
	Grafted	8.58 b	7.38 bc	7.40 bc	7.79
	Average	9.42 A	6.98 B	7.48 B	
CV (%5):0.05					
Prob>f	Grafted/ungrafted 0.2644	Irrigated / Rainfed <.0001	Grafted/ungrafted* Irrigated / Rainfed 0.0012		
2019	Ungrafted	9.70 a	7.03 c	8.15 a-c	8.29

	Grafted	8.70 ab	8.43 a-c	7.67 bc	8.27
	Average	9.20 A	7.73 B	7.91 B	
CV (%5):0.06					
	Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed		
Prob>f	0.9949	0.0011	0.0096		

The mean values given in different capital letters in the same column and row and the mean values of the interaction in the middle of the table with lower case letters were statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

In the Paskal variety, one month after harvest, higher results were obtained in 2018 than those grafted in terms of TA (0.33%) and the highest value was obtained from those in rainfed conditions (0.34%), when compared with marketable fruits in irrigated and rainfed conditions on the land and preserved fruits. In the interaction between grafted and ungrafted, marketable fruits in irrigated and rained conditions in the field and preserved fruits, the highest value was obtained from the grafted Pascal variety (0.41%) under irrigated conditions and the lowest value was obtained from the ungrafted Pascal variety (0.22%) in irrigated conditions. In 2019, the difference between all applications was found to be statistically insignificant (Table 8).

Table 8. TA(%) amounts of the grafted and ungrafted Paskal variety preserved 1 month after harvest, in irrigated and rainfed conditions in the field in 2018 and 2019.

Years	Grafted/Ungrafted	Preserved	Irrigated	Rainfed	Average
2018	Ungrafted	0.28 bc	0.22 c	0.27 bc	0.26 B
	Grafted	0.31 b	0.29 bc	0.41 a	0.33 A
	Average	0.29 B	0.25 B	0.34 A	
CV (%5):0.07					
	Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed		
Prob>f	<.0001	0.0002	0.0320		
2019	Ungrafted	0.20	0.20	0.20	0.20
	Grafted	0.24	0.20	0.19	0.21
	Average	0.22	0.20	0.19	
CV (%5):0.07					
	Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed		
Prob>f	0.6357	0.1494	0.0904		

The mean values given in different capital letters in the same column and row and the mean values of the interaction in the middle of the table with lower case letters were statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

In the Paskal variety, one month after the harvest, grafting did not have a statistical effect in terms of pH in 2018, while the highest value was obtained from the ungrafted pascal in 2019. When compared in terms of marketable fruits in irrigated and rainfed conditions in the field and preserved fruits, the highest values were obtained from the preserved ones in 2018 and 2019

(6.30 and 6.43). In the interaction between grafted and ungrafted and marketable fruits in irrigated and rainfed conditions in the field and preserved fruits, the highest values were obtained from the preserved and ungrafted (6.41 and 6.65) Paskal variety (Table 9).

Table 9. pH amounts of the grafted and ungrafted Paskal variety preserved 1 month after harvest, in irrigated and rainfed conditions in the field in 2018 and 2019.

Years	Grafted/Ungrafted	Preserved	Irrigated	Rainfed	Average
2018	Ungrafted	6.41 a	5.83 c	5.84 c	6.00
	Grafted	6.19 b	5.83 c	6.03 bc	6.02
	Average	6.30 A	5.83 B	5.93 B	
CV (%5):0.02					
Prob>f	Grafted/ungrafted 0.7695		Irrigated / Rainfed <.0001	Grafted/ungrafted* Irrigated / Rainfed 0.0007	
2019	Ungrafted	6.65 a	6.24 b	6.47 ab	6.45 A
	Grafted	6.21 b	6.31 b	5.74 c	6.08 B
	Average	6.43A	6.27 B	6.10 C	
CV (%5):0.02					
Prob>f	Grafted/ungrafted <.0001		Irrigated / Rainfed <.0001	Grafted/ungrafted* Irrigated / Rainfed <.0001	

The mean values given in different capital letters in the same column and row and the mean values of the interaction in the middle of the table with lower case letters were statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

In the Crimson Tide variety, one month after the harvest, the highest SSC grafting was obtained in 2018 and there was no statistical effect of grafting in 2019. When the marketable fruits in the irrigated and rainfed conditions in the field were compared with the fruits preserved, the highest value was 8.10 in 2018, while there was no difference between the applications in 2019.

In the interaction between grafted and ungrafted and marketable fruits in irrigated and rainfed conditions in the field and preserved fruits, insignificant was obtained in 2018; in 2019, it was taken from the irrigated and ungrafted Crimson Tide variety (8.40%) (Table 10).

Table 10. SSC (%) amounts of the grafted and ungrafted Crimson Tide variety preserved 1 month after harvest, in irrigated and rainfed conditions in the field in 2018 and 2019.

Years	Grafted/Ungrafted	Preserved	Irrigated	Rainfed	Average
2018	Ungrafted	7.15	5.98	6.81	6.65 B
	Grafted	9.05	6.50	7.40	7.65 A
	Average	8.10 A	6.24 C	7.10 B	
CV (%5):0.06					
Prob>f	Grafted/ungrafted 0.0016		Irrigated / Rainfed <.0001	Grafted/ungrafted* Irrigated / Rainfed 0.1454	
2019	Ungrafted	8.10 ab	8.40 a	7.03 b	7.84
	Grafted	7.43 ab	7.75 ab	7.93 ab	7.71
	Average	7.77	8.08	7.48	
CV (%5):0.04					
Prob>f	Grafted/ungrafted 0.5517		Irrigated / Rainfed 0.0773	Grafted/ungrafted* Irrigated / Rainfed 0.0049	

The mean values given in different capital letters in the same column and row and the mean values of the interaction in the middle of the table with lower case letters were statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

There was no statistical difference in terms of TA in all applications in 2018, one month after harvest, in Crimson Tide variety. In 2019, the highest results were obtained from the grafted ones (0.25), and the highest values were obtained from the ones in irrigated conditions (0.27), when compared with the marketable fruits in the irrigated and rainfed conditions in the field and the preserved fruits. The interactions in both years were insignificant (Table 11).

Table 11. TA(%) amounts of the grafted and ungrafted Crimson Tide variety preserved one month after harvest, in irrigated and rainfed conditions in the field in 2018 and 2019.

Years	Grafted/Ungrafted	Preserved	Irrigated	Rainfed	Average
2018	Ungrafted	0.34	0.34	0.34	0.34
	Grafted	0.40	0.37	0.37	0.38
	Average	0.37	0.36	0.35	
CV (%5):0.10					
Prob>f	Grafted/ungrafted 0.0822	Irrigated / Rainfed 0.7621	Grafted/ungrafted* Irrigated / Rainfed 0.7571		
2019	Ungrafted	0.13	0.24	0.21	0.19 B
	Grafted	0.16	0.30	0.28	0.25 A
	Average	0.15C	0.27 A	0.24 B	
CV (%5):0.05					
Prob>f	Grafted/ungrafted <.0001	Irrigated / Rainfed <.0001	Grafted/ungrafted* Irrigated / Rainfed 0.3341		

The mean values given in different capital letters in the same column and row and the mean values of the interaction in the middle of the table with lower case letters were statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

One month after harvest in Crimson Tide, those grafted in 2018 had a pH (5.95); In 2019, those who were not grafted (6.57) came to the fore. When the marketable fruits in the irrigated and rainfed conditions in the field were compared with the fruits preserved, the ones that were irrigated in 2018 (5.83) and those that were preserved in 2019 (7.17) received the highest values. In the interaction between grafted and ungrafted marketable fruits in irrigated and rainfed conditions in the field and preserved fruits, insignificant was obtained in 2018; In 2019, it was taken from the preserved ungrafted (7.36) Crimson Tide variety (Table 12).

Table 12. pH amounts of the grafted and ungrafted Crimson Tide variety preserved one month after harvest, in irrigated and rainfed conditions in the field in 2018 and 2019.

Years	Grafted/Ungrafted	Preserved	Irrigated	Rainfed	Average
2018	Ungrafted	5.48	5.58	5.35	5.47 B
	Grafted	5.97	6.07	5.82	5.95 A
	Average	5.72 AB	5.83 A	5.59 B	
CV (%5):0.03					
Prob>f	Grafted/ungrafted <.0001	Irrigated / Rainfed 0.0012	Grafted/ungrafted* Irrigated / Rainfed 0.9756		
2019	Ungrafted	7.36 a	6.30 c	6.06 d	6.57 A
	Grafted	6.98 b	6.19 cd	6.31 c	6.49 B

	Average	7.17 A	6.24 B	6.18 B	
CV (%5):0.01					
	Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed		
Prob>f	0.0271	<.0001	<.0001		

The mean values given in different capital letters in the same column and row and the mean values of the interaction in the middle of the table with lower case letters were statistically significant; those without lettering were found to be insignificant ($p < 0.05$).

4. Conclusions

In the study carried out to investigate sunburn in watermelon, it was observed that the rates of sunburn were higher in Paskal variety with dark skin color in 2018 and 2019 compared to the striped Crimson Tide variety and there were almost no marketable fruits in the fruits of grafted and ungrafted all applications of Paskal variety.

In the Crimson Tide variety included in the experiment, it was observed that the rate of marketable fruits after one month was higher in the fruits of the plants in which grafting and irrigation were applied to the irrigated and rainfed applications left in the field. While there was almost no marketable fruit in both years in Paskal variety with dark skin color, it was possible to find marketable fruits in both years in Crimson Tide variety, although it varied according to years. Selecting types with light colored rinds, which appear to be less susceptible to sunburn than dark-rinded varieties, may help reduce the risk of sunburn injury (Maynard and Hopkins (1999) and Shrefler et al. (2015).

SSC is significantly affected by rootstocks in grafted production as well as by cultivars (Yetisir and Sarı, 2003; Karaağaç, 2013, Çandır et al, 2013). Moreno et al. (2016) found significant differences in SSC in grafted seeded watermelons, but they did not find a significant difference in seeded watermelons. In some studies, decreases in SSC were also reported with grafting (Alexopoulos and et al., 2007; Davis and Perkins-Veazie, 2008; Rouphael et al., 2010; Kyriacou et al., 2018). On the other hand, the positive effect of rootstock use on SSC was reported by some researchers (Bekhradi et al., 2011; Mohamed et al., 2012; Gölükcü and Tokgöz, 2018; Garcia-Lozano et al., 2019). The pH of watermelon fruit varies between 5.5 and 5.8 depending on maturity (Candir et al., 2013; Soteriou et al., 2014). The SSC regards to findings of Özdemir et al. (2018) and Çandır et al. (2021) were similar to the results of this study.

The decrease in acidity and increase in pH are slow in watermelons grafted on Cucurbita rootstocks (Proietti et al., 2008; Soteriou et al., 2014). High acidity detected in grafted watermelons may be an additional indicator of late ripening of fruits in grafted plants, but unlike

sugar content, acidity decreases linearly with ripening and becomes progressively higher in grafted watermelons throughout the ripening period (Soteriou et al., 2014).

Similar to our study's findings, it was reported in various studies that TA content increases and decreases in parallel with the changes in fruit juice pH during storage, and that there was a higher TA content in grafted plants (Proietti et al., 2008; Çandır et al., 2013; Özdemir et al., 2018; Çandır et al., 2021). Çandır et al. (2021) pH value of fruit juice Unlike our findings, it was reported that the concentration decreased slightly during storage. But in this research, grafted and ungrafted watermelons were analyzed for pH four times (0, 7, 14, and 21 days in storage at 0°C) during storage. For this reason, since only the pH values 21 days after being put into storage were more accurate, these results were similar to the results in the current study. It is reported that the postharvest behavior of apple fruit is affected by exposure to high sunlight and temperature before harvest (Woolf and Ferguson, 2000; Rudell et al., 2008). According to Bergh et al. (1980), sunlight diminishes the apple fruit's ability to be stored. Schrader et al, (2009) found that SSC increased as the severity of sunburn browning increased in apples; however, they reported that TA decreased markedly with more severe sunburn damage. Racskó et al. (2009) reported that the level of sunburn damage varies according to apple cultivars.

In general, the rate of sunburn was low in cultivars with a strong plant habitus and not very large fruit (5-6 kg); It can be said that grafting minimized the recess structure and plant feeding problems and increased plant growth and feeding the plant continuously with irrigation would reduce the rate of sunburn. There was no problem in terms of sunburn in farmer conditions in early cultivation in the Çukurova region of Turkey. Because, since the product is put on the market in April-May, sunburn does not occur in this period, since both the air temperature and sunbathing are not at a level to cause sunburn. In the cultivation that takes place in open field conditions, it is offered to the market in May-June. In case of good irrigation and fertilization, there is no risk of sunburn on fruits or very low (very large fruit varieties). There may be losses due to sunburn in years on the basis of producers. These losses occur 7-10 days before the watermelon reaches the harvest maturity, as a result of the effects of the extreme heat brought by the northerly winds that blow for 2-3 days in some years and an event that burns the plant habitus. However, another type of sunburn is the type of damage that producers face because they keep their products in the field while waiting for a suitable buyer or price for their watermelons.

Most of the watermelon seeds used in Türkiye are hybrid varieties. While almost all of the greenhouse growing is done with hybrid varieties, both hybrid and open pollinated varieties can

be preferred in the open. Since 1964, there are 355 registered watermelon varieties as of February 2021 (TTSM, 2021). These include both early and late varieties. All varieties can be grown in every region by earliness, plant habitus, the region and growing time, grafted and ungrafted conditions and continuous irrigation and maintenance.

The burn scale rates is high in ungrafted cultivars, and the burn scale rates increases in unirrigated cultivars. Therefore, the weighted scale average was higher in ungrafted and unirrigated cultivars. It was observed that there was not much difference between the grafted and ungrafted varieties in terms of SSC, but it was high in the stored ones. It was observed that there was not much difference between grafted and ungrafted with preserved, irrigated, and rainfed applications in terms of TA (%). The pH amount was generally higher in the stored ones. As a conclusion, it is recommended to use grafted seedlings and to continue irrigation in places where sunburn may occur. However, creating favorable conditions for strong vine growth that shades the watermelon fruit is the greatest way to avoid sunburn damage.

Acknowledgements

The author is gateful to the Agricultural Insurance Pool Management Company (TARSIM). And, I also would like to thank Antalya Seedling Company and Genetika Seed Company for providing us grafted and ungrafted seedlings on different rootstocks.

Referances

Alexopoulos, A., Kondylis, A., Passam, H., 2007. Fruit yield and quality of watermelon in relation to grafting. J Food Agric Environ, 5: 178-179.

Baameur, A., Hartz, T.K., Turini, T., Natwick, E., Takele, E., Aguiar, J., Cantwell, M. and Mickler, J. 2009. Watermelon production in California. UC Vegetable Research & Information Center, University of California at Davis. Vegetable Production Series, Publication 7213. 5 p. Versión electrónica en: http://anrcatalog.ucdavis.edu/pdf/7213.pdf

Bekhradi, F., Kashi, A., Delshad, M., 2011. Effect of three cucurbit rootstocks on vegetative and yield of 'Charleston Grey' watermelon. Int J Plant Prod., 5: 105–109.

Bergh, O., Franken, J., van Zyl, E. J., Kloppers, F., Dempers, A. 1980. Sunburn on apples – preliminary results of an investigation conducted during the 1978/79 season. Deciduous Fruit Grower 30: 8–22.

Bertelsen, D., Harwood, J., Hoff, F., Lee, H., Perez, A., Pollack, S., Somwaru, A. and Zepp, G. 1994. Watermelons: An economic assessment of the feasibility of providing multiple-peril crop insurance. Prepared by the Economic Research Service, USDA, in cooperation with the

University of California for the Federal Crop Insurance Corporation November 22. https://legacy.rma.usda.gov/pilots/feasible/PDF/wtrmelon.pdf

Camen, D., Coman, N., Dragomir, C., Nistor, E., Popescu, CIancu, T., Stanciu, S., Danci, M., Petcov, A., Moatăr, M. and Sala, F. 2018. The influence of fertilization and storage conditions on the production quality in watermelon. Journal of Horticulture, Forestry and Biotechnology, Volume 22(1), 136- 143, www.journal-hfb.usab-tm.ro.

Çandır, E., Yetişir, H., Karaca, F. and Üstün, D. 2013. Phytochemical characteristics of grafted watermelon on different bottle gourds (*Lagenaria siceraria*) collected from the Mediterranean region of Turkey. Turkish Journal of Agriculture and Forestry 37: 443– 456.

Çandır, E., Özdemir, A.E., Yetişir, H., Aras, V., Arslan, Ö., Baltaer, Ö. and Ünlü, M. 2021. Effects of chilling injury, physical and biochemical changes on grafted watermelons stored at low temperature. Horticultural Studies, 38 (2): 71–84. doi:10.16882/hortis.951086

Davis, A.R., Perkins-Veazie, P., Sakata, Y., López-Galarza, S., Maroto, J.V., Lee, S.G., Huh, Y.C., Sun, Z., Miguel, A., King, S., Cohen, R., Lee, J.M., 2008. Cucurbit Grafting. Crit Rev Plant Sci, 27: 50-74.

Evans, R.G., 1993. Part one: Designing and operating overtree evaporative cooling sys-tems for apples. Good Fruit Grower. 6, 23–27.

FAOSTAT, 2020. https://www.fao.org/faostat/en/#data/QCL (date: 19 September 2022)

Felicetti, D.A. and Schrader, L.E. 2009. Changes in pigment concentrations associated with the degree of sun- burn browning of 'Fuji' apple. J. Ame. Soc. Hortic. Sci.133: 27–34. doi:10.21273/JASHS.133.1.27

Garcia-Lozano, M., Dutta, S.K., Natarajan, P., Tomason, Y.R., Lopez, C., Katam, R., Levi, A., Nimmakayala, P., Reddy, U.K., 2019. Transcriptome changes in reciprocal grafts involving watermelon and bottle gourd reveal molecular mechanisms involved in increase of the fruit size, rind toughness and soluble solids. Plant Molecular Biology, 102:213-223

Gindaba, J., Wand, S.J., 2005. Comparative effects of evaporative cooling, kaolin particle film, and shade net on sunburn and fruit quality in apples. HortScience 40 (3), 592–596.

Glenn, D.M., Prado, E., Erez, A., McFerson, J., Puterka, G.J., 2002. A reflective, processedkaolin particle film affects fruit temperature, radiation reflection, and solar injury in apple. J. Am. Soc. Hortic. Sci. 127 (2), 188–193.

Gölükcü, M., Tokgöz, H., 2018. Variation in sugar, organic acid and volatile flavor compounds of watermelon (*Citrullus lanatus*) grafted on different rootstocks at different harvest time. Akademik Gıda, 16(4): 381-386.

442 Güçdemir, İ.H. 2012. Plant Nutrition recipe preparation technique based on soil analysis and
443 practical examples. In Plant Nutrition (Ed. Karaman, M.R.) 961–1066.
444 JMP, 2007. Statistics and graphics guide. SAS Institute, Cary, North Carolina, USA.
445 Liu, J.R., Choi, P.S and Kim, Y.S. 2001. Transgenic watermelon (*Citrullus lanatus*).
446 biotechnology in agriculture and forestry, 124–131. doi:10.1007/978-3-642-56901-2_9
447 Karaağaç, O., 2013. Determination of watermelon rootstock potential of chestnut squash
448 (*Cucurbita maxima* Duch) and pumpkin (*C. moschata* Duch.) genotypes collected from the
449 Black Sea region. Doctoral Thesis, On Dokuz Mayıs University, Institute of Sciences,
450 Department of Horticulture, 238s, Samsun.
451 Kyriacou, M.C., Leskovar, D.I., Colla, G., Rouphael, Y., 2018. Watermelon and melon
452 fruit quality: The genotypic and agro-environmental factors implicated. Sci Hortic., 234:
453 393-408.
454 Maynard DN and Hopkins DL (1999). Watermelon fruit disorders. HortTechnology, 9(2)
455 p.155–161. doi:10.21273/HORTTECH.9.2.155
456 Mohamed, F., El-Hamed, K., Elwan, M., Hussien, M., 2012. Impact of grafting on
457 watermelon growth, fruit yield and quality. Veg Crops Res Bull 76: 99-118.
458 Moreno, B., Jacob, C., Rosales, M., Krarup, K., Contreras, S., 2016. Yield and quality of grafted
459 watermelon grown in a field naturally infested with Fusarium wilt. HortTechnology, 26:
460 453-459.
461 Munné-Bosch, S. and Vincent, C. 2019. Physiological mechanisms underlying fruit sunburn.
462 Critical Reviews in Plant Sciences, 1–18. doi:10.1080/07352689.2019.1613320
463 Özdemir, A.E., Çandir, E., Yetişir, H., Aras, V., Arslan, Ö., Baltaer, Ö., Üstün, D. and Ünlü,
464 M. 2018. Rootstocks affected postharvest performance of grafted 'Crisby' and 'Crimson Tide'
465 watermelon cultivars. J. Agric. Sci. 24: 453–462.
466 Proietti, S., Rouphael, Y., Colla, G., Cardarelli, M., De Agazio, M., Zacchini, M., Rea, E.,
467 Moscatello, S. and Battistelli, A. 2008. Fruit quality of mini-watermelon as affected by grafting
468 and irrigation regimes. Journal of The Science of Food and Agriculture 88: 1107– 1114.
469 Racskó, J., Szabó, Z., Miller, D. D., Soltész, M., Nyéki, J. 2009. Sunburn incidence of apples
470 is affected by rootstocks and fruit position within the canopy but not by fruit position on the
471 cluster. International Journal of Horticultural Science, 15(4), 45–51.
472 https://doi.org/10.31421/IJHS/15/4/839

473 Racsko, J. and Schrader, L.E. 2012. Sunburn of apple fruit: Historical background, recent
474 advances and future perspectives. Critical Reviews in Plant Sciences, 31(6), 455–504.
475 doi:10.1080/07352689.2012.696453
476 Rouphael, Y., Schwarz, D., Krumbein, A., Colla, G., 2010. Impact of grafting on product
477 quality of fruit vegetables. Sci Hortic., 127: 172-179.
478 Rudell, D.R., Mattheis, J.P., and Curry, E.A. 2008. Prestorage ultraviolet-white light irradiation
479 alters apple peel metabolome. J. Agric. Food Chem. 56:1138–1147.
480 Schrader, L. E., Zhang, J., Sun, J., Xu, J., Elfving, D. C., and Kahn, C. 2009. Postharvest
481 changes in internal fruit quality in apples with sunburn browning. J. Amer. Soc. Hort. Sci. 134:
482 148–155.
483 Shrefler, J., Brandenberger, L., Rebek, E., Damicone, J. and Taylor, M. 2015. Watermelon
484 production. Oklahoma Cooperative Extension, Oklahoma State University, Oklahoma, United
485 States of America, Fact Sheets, HLA-6236. Available online at (http://osufacts.okstate.edu).
486 Soteriou, G.A., Kyriacou, M.C., Siomos, A.S., Gerasopoulos, D. 2014. Evolution of
487 watermelon fruit physicochemical and phytochemical composition during ripening as affected
488 by grafting. Food Chem., 165: 282-289.
489 TTSM, 2021. Republic of Türkiye Ministry of Agriculture and Forestry Variety Registration
490 and Seed Certification Center, Standard seed register list (Vegetable varieties)(February).
491 TSI, 2021. Turkish Statistical Institute web page.
492 https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr. Last access date: 06.07.2021
493 Yetisir, H., Sari, N., 2003. Effect of different rootstock on plant growth, yield and quality
494 of watermelon. Aust. J. Exp. Bot., 43: 1269-1274.
495 Woolf, A. B., Ferguson, I. B. 2000. Postharvest responses to high fruit temperatures in the field.
496 Postharvest Biol. Technol. 21: 7–20.
497 Wünsche, J. N., Bowen, J., Ferguson, I., Woolf, A., McGhie, T., 2002. Sunburn on applescauses
498 and control mechanisms. In XXVI International Horticultural Congress: Key Processes in the
499 Growth and Cropping of Deciduous Fruit and Nut Trees. 636, 631–636.