

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; Racsco and Schrader, 2012). Photodamage to the fruits of different crops grown in temperate areas as a result of excessive

35 heat and/or light radiation causes sunburn, a physiological disease that can be seen (visible and
36 ultraviolet light). The main reason is thought to be an increase in the production of reactive
37 oxygen species that cause oxidative damage due to the fruit's inability to recover from stress.
38 Consumers may not like the distinctive morphological and structural phenotype that results
39 from this and farmers may experience significant production losses as a result. Berries contain
40 a wide range of defense mechanisms, including accumulation of heat shock proteins and
41 photoprotective pigments, as well as the manufacture of antioxidants, to attenuate or minimize
42 the generation of reactive oxygen species and deactivation of the photosynthetic apparatus
43 (Munné-Bosch and Vincent, 2019). However, when stress factors that change fruit surface
44 approach a particular level, these mechanisms lose their effectiveness (both duration and
45 intensity) (Munné-Bosch and Vincent, 2019). **Growers use different cultural and sunburn
46 control techniques, such as choosing rootstocks that are less susceptible to sunburn (Wünsche
47 et al., 2002), coating fruit with a reflecting material (Glenn et al., 2002), using shading nets
48 (Gindaba and Wand, 2005), and evaporative cooling (Evans, 1993). Although they can reduce
49 the likelihood of obtaining a sunburn, these cultural practices cannot entirely negate its negative
50 effects.** Sunburn is a condition that affects many different fruits and vegetables, not just one
51 particular type or variety. Watermelon is one of these vegetables. Sunburn marks will appear
52 on the watermelon's upper surface where sunlight is more prevalent. The upper surface of the
53 watermelon fruit has a gray region where the skin pigment has been damaged as a result of the
54 pigment degradation process, when the temperature on the sunny side of the fruit exceeds
55 41.6°C (107°F) (Maynard ve Hopkins, 1999). Cucumber and pepper fruits should be taken into
56 consideration in conjunction with high temperatures and intense light, although the cause of
57 sunburn in watermelon fruit is still unknown (Maynard ve Hopkins, 1999). The average
58 watermelon peel temperature hits 41.6 °C in the sun and 36.1 °C in the shade at a time when
59 the ambient air temperature is 31.9 °C (Maynard ve Hopkins, 1999). The easiest technique to
60 avoid sunburn damage, though, is to create the right conditions for a sturdy base structure that
61 can provide shade for the watermelon fruit (Maynard and Hopkins, 1999; Camen et al, 2018).
62 Dark green and striped watermelons are more likely to get sunburned than light green and gray-
63 green kinds (Maynard and Hopkins, 1999; Shrefler et al., 2015).
64 **It has been observed that complaints to the Agricultural Insurance Pool Management Company
65 (TARSIM) have increased in recent years in Türkiye due to sunburn and this study was carried
66 out at Alata Horticultural Research Institute Türkiye in order to supported by TARSIM.**

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

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75 **2. Material and Method**

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

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

83 The experiment was established on April 05 in 2018 and on March 27 in 2019. Soil analysis
 84 results are given in Table 1. The seedlings were planted on April 21 in the area with coordinates
 85 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
 86 34°20'28.51"E in 2019. The seedlings were planted with 2.5 x 0.7 m spacings and distances on
 87 the prepared banks with a width of **0.7 m** and a height of **0.4 m**, covered with black mulch.

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Table 1. Soil analysis of used parcels.

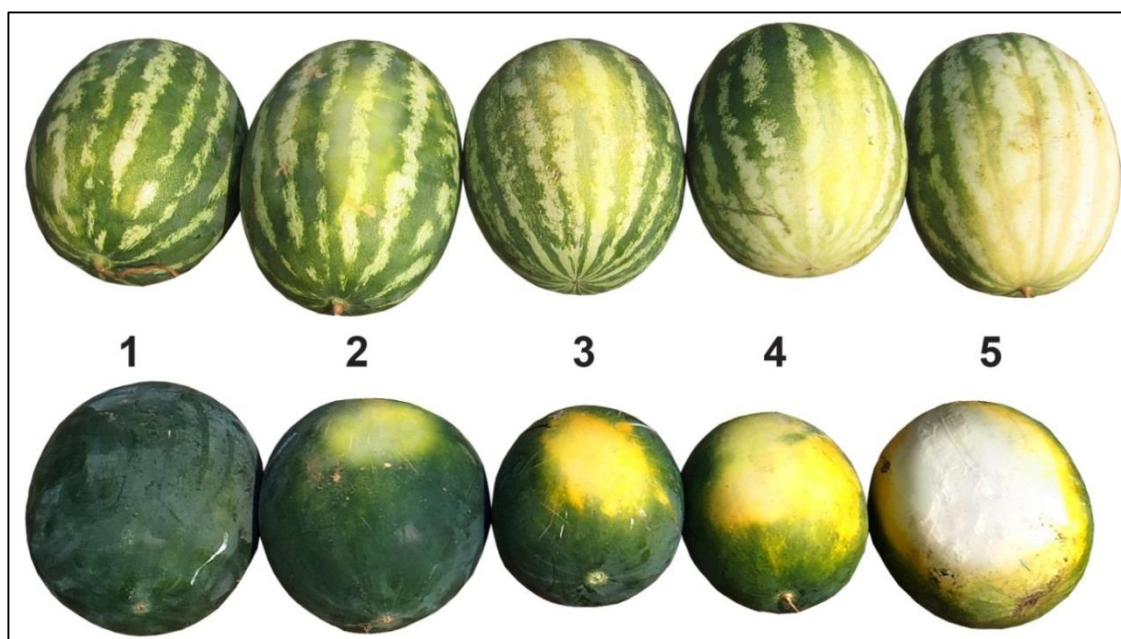
Year	Analyzes	Limit Values	Analysis Results (0-30 cm)
2018	Texture (100 g/ml)	30-50	38.00 (loamy)
	Total Calcitic (CaCO ₃ %)	5-15	35.40 (high calcareous)
	Salinity E.C. ds/m (25 °C)	0-0.8	0.35 (slightly salty)
	Organic matter (%)	3-4	3.30 (optimum)
	pH 1: 2,5	6.0-7.0	7.56 (slightly high)

	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 (CaCO ₃ %)	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)

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98 The experiment was established in a randomized completely block design with four replications
 99 and 20 plants in each replication. Irrigation was done with drip irrigation system. Soil analysis
 100 was carried out in the experimental area and fertilizations were given as pure substance as 14-
 101 16 kg/da N, 8-10 kg/da P₂O₅, 6-8 kg/da K₂O according to the analysis results (Güçdemir, 2012).
 102 Spraying against spider mites and other pests was done as soon as they were seen. Weed control
 103 was done mechanically and manually.

104 The normal harvest time of the fruits was determined as 09 July in 2018 and 02 July in 2019,
 105 when the auricle and tendril were dry. From this stage onwards, the fruit samples of the varieties
 106 taken from the grafted and ungrafted watermelon varieties were placed in the cold storage with
 107 4°C and 95% relative humidity. In addition, half of the grafted and ungrafted watermelon plants
 108 in the field trial were irrigated and the other half unwatered and the trial was continued for one
 109 more month, starting from the harvest date. One month after harvest, the sunburn rates in each
 110 plot were determined on a 1-5 scale value (Figure 1). The weighted scale average was calculated
 111 by taking the arithmetic average of all the scale values taken separately for each application and
 112 variety of fruits.



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

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116 Although sunburn is generally thought of as a disorder that only affects the appearance of the
117 skin of a watermelon, this research shows that it also directly affects the internal quality
118 characteristics of the fruit. Schrader et al. (2009) investigated the changes in SSC and TA, which
119 are parameters affecting fruit core quality, in their study related to the increase in the severity
120 of sunburn. As in this study, SSC, TA and pH values were examined as quality parameters. One
121 month after the harvest, fruit samples were taken from the fruits in the storage at 4°C and from
122 the ones whose scale value was 1 (slightly burned or not burned) and cultivated under irrigated
123 and rainfed conditions in field conditions and water total soluble solid (SSC %), titratable
124 acidity (TA %) and pH levels of these fruits were investigated. Total amount of total soluble
125 solid [SSC] was measured by hand refractometer (Atago ATC-1E Model (Atago Co. Ltd.,
126 Tokyo, Japonya), titratable acidity [TA], a potentiometric method (5 ml of the obtained fruit
127 juice was taken, and the acidity value was measured with the help of the 0.1 N NaOH solution],
128 and the pH reached 8.1. These measurements have no direct effect on quality-related sunburn
129 but were made to give an idea of the consumer acceptability of sunburn and non-sunburn.
130 The climate values of 2018 and 2019, when the research was conducted, are given in Table 2.

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Table 2. Climatic data of the trial area.

Year	Climate Parameters	April	May	June	July	August
2018	Total global solar radiation (kWsaat/m ²)	168.5	186.9	180.8	222.8	199.1
	Max. global solar radiation (watt/m ²)	463 800	480 000	485 400	478 800	438 000
	Total global radiation (kWsaat/m ²)	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÷m ²)	6.4	0.8	2.0	3.2	4.4	
2019	Total global solar radiation (kWsaat/m ²)	160.3	210.6	208.9	224.8	192.8
	Max. global solar radiation (watt/m ²)	454 200	493 800	501 600	502 800	459 748
	Total global radiation (kWsaat/m ²)	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	

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136 **2.1. Statistical analysis**

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

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144 **3. Results and Discussion**

145 In 2018, the ungrafted Paskal watermelon cultivar under irrigated conditions had a scale 1
 146 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
 147 was 35.43%. When we look at the burn rate of the ungrafted Paskal watermelon variety in the
 148 scale based on rainfed, burn rate of scale 1 was 0.0%, scale 2 was 8.98%, scale 3 was 26.93%,
 149 scale 4 was 28.85% and scale 5 was 35.15%. The burn rate of Paskal watermelon variety
 150 grafted on Gürdal in irrigated conditions, scale 1 was 4.35%, scale 2 was 20.03%, scale 3 was
 151 40.25%, scale 4 was 27.00% and scale 5 was 8.48%. Grafted Paskal watermelon variety has a
 152 burn rate of, in the scale under rainfed conditions; scale 1 was 0.00%, scale 2 was 8.90%,
 153 scale 3 was 18.05%, scale 4 was 45.25% and scale 5 was 26.60%. The burn rate of the ungrafted
 154 Paskal watermelon variety in irrigated conditions in 2019, scale 1 was 0.00%, scale 2 was
 155 2.35%, scale 3 was 5.45% scale 4 was 39.63% and scale 5 was 52.55%. The burn rate of the
 156 ungrafted Paskal watermelon variety under rainfed conditions, scale 1 was 0.0%, scale 2 was
 157 2.42%, scale 3 was 12.93%, scale 4 was 37.13% and scale 5 was 47.53%. The burn rate of the
 158 grafted Paskal watermelon variety under irrigated conditions, scale 1 was 1.78%, scale 2 was
 159 8.45%, scale 3 was 16.85%, scale 4 was 35.53% and scale 5 was 37.40%. The burn rate of the
 160 grafted Paskal watermelon variety under rainfed conditions, scale 1 was 0.0%, scale 2 was
 161 3.53%, scale 3 was 6.28%; scale 4 was 32.05%, scale 5 was 58.13% (Table 3).

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163 **Table 3.** The rates of sunburn 1 month after harvest in 2018 and 2019 in irrigated and rainfed
 164 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

165

166 When we evaluate the combination of Paskal variety with ungrafted and grafted on Gürdal
167 according to the weighted scale averages in 2019, it is seen that the sunburn rate of the grafted
168 (3.51) is less affected than the ungrafted (3.87). It is also seen that continuing irrigation (3.50)
169 after harvest reduces the rate of sunburn compared to being left rainfed (3.89). The sunburn rate
170 of Paskal variety grafted on Gürdal rootstock grown in irrigated conditions was found to be at
171 least (3.15). When we evaluate the combination of Paskal variety with ungrafted and grafted on
172 Gürdal for 2019, it was observed that grafted (4.22) sunburn rate was less affected than
173 ungrafted (4.36). It was also observed that continuing irrigation (4.20) after harvest reduced the
174 rate of sunburn compared to being left rainfed (4.37). The sunburn rate of Paskal variety grafted
175 on Gürdal rootstock grown in irrigated conditions was determined to be at least (3.98) (Table
176 4).

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181 **Table 4.** Weighted Scale Averages of grafted and ungrafted Paskal variety 1 month after harvest
182 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				
Grafted/ungrafted		Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed	
Prob>f		0.0011	0.0006	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				
Grafted/ungrafted		Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed	
Prob>f		0.0067	0.0025	<.0001

183 The mean values given in different capital letters in the same column and row and the mean values of the interaction
184 in the middle of the table with lower case letters were statistically significant; those without lettering were found
185 to be insignificant ($p < 0.05$).
186

187 The burn rate of the ungrafted Crimson Tide watermelon variety under irrigated conditions in
188 2018, scale 1 was 3.60%, scale 2 was 11.48%, scale 3 was 23.00%, scale 4 was 30.95%, scale
189 5 was 31.05%. The burn rate of the ungrafted Crimson Tide watermelon variety under rainfed

190 conditions in 2018, scale 1 was 1.95%, scale 2 was 6.55%, scale 3 was 18.58%, scale 4 was
 191 27.45%, scale 5 was 45.50%. The burn rate of the grafted Crimson Tide watermelon variety
 192 under irrigated conditions in 2018, scale 1 was 6.88%, scale 2 was 11.45%, scale 3 was 12.08%,
 193 scale 4 was 35.68%; scale 5 was 33.95%. The burn rate of the grafted Crimson Tide watermelon
 194 variety under rainfed conditions in 2018, scale 1 was 3.48%, scale 2 was 9.85%, scale 3 was
 195 8.85%, scale 4 was 28.28, scale 1 was 49.58%. The burn rate of the ungrafted Crimson Tide
 196 watermelon variety under irrigated conditions in 2019, scale 1 was 13.03%, scale 2 was 10.98%,
 197 scale 3 was 10.25%, scale 4 was 28.83%, scale 5 was 36.90%. The burn rate of the ungrafted
 198 Crimson Tide watermelon variety under rainfed conditions in 2019, scale 1 was 3.28%, scale 2
 199 was 3.88%, scale 3 was 10.83%, scale 4 was 31.30% and scale 1 was 50.75%. The burn rate of
 200 the grafted Crimson Tide watermelon variety under irrigated conditions in 2019, scale 1 was
 201 24.90%, scale 2 was 17.75%, scale 3 was 17.05%, scale 4 was 23.38%, scale 1 was 16.93%.
 202 The burn rate of the grafted Crimson Tide watermelon variety under rainfed conditions in 2019,
 203 scale 1 was 10.70%, scale 2 was 11.90%, 3 was 23.58%, scale 4 was 22.55%, scale 5 was
 204 31.30% (Table 5).

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208 **Figure 5.** The rates of sunburn 1 month after harvest in 2018 and 2019 in irrigated and rainfed
 209 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

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211 When we evaluated the combination of Crimson Tide watermelon ungrafted and grafted on
 212 NUN9075 according to the weighted scale averages in 2018, no statistical difference was found
 213 in terms of sunburn rates. Continuing to irrigate after harvest (3.76) seems to reduce the rate of
 214 sunburn compared to leaving it based on rainfed (4.09). When we evaluated the combination of
 215 the Crimson Tide variety ungrafted and grafted on NUN9075 for 2019, it is seen that grafted
 216 (3.21) sunburn rate was less affected than ungrafted (3.94). Continuing to irrigate after harvest

217 (3.28) seems to reduce the rate of sunburn compared to being left rainfed (3.87). **The**
 218 **interactions in both years were insignificant** (Table 6).

219
 220 **Figure 6.** Weighted Scale Averages of grafted and ungrafted Crimson Tide variety 1 month
 221 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														
<table border="0" style="width:100%; text-align:center;"> <tr> <td></td> <td>Grafted/ungrafted</td> <td>Irrigated / Rainfed</td> <td>Grafted/ungrafted* Irrigated / Rainfed</td> <td></td> </tr> <tr> <td>Prob>f</td> <td>0.3164</td> <td><.0001</td> <td>0.8267</td> <td></td> </tr> </table>						Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed		Prob>f	0.3164	<.0001	0.8267	
	Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed											
Prob>f	0.3164	<.0001	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														
<table border="0" style="width:100%; text-align:center;"> <tr> <td></td> <td>Grafted/ungrafted</td> <td>Irrigated / Rainfed</td> <td>Grafted/ungrafted* Irrigated / Rainfed</td> <td></td> </tr> <tr> <td>Prob>f</td> <td><.0001</td> <td><.0001</td> <td>0.7389</td> <td></td> </tr> </table>						Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed		Prob>f	<.0001	<.0001	0.7389	
	Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed											
Prob>f	<.0001	<.0001	0.7389											

222 The mean values given in different capital letters in the same column and row and the mean values of the interaction
 223 in the middle of the table with lower case letters were statistically significant; those without lettering were found
 224 to be insignificant ($p < 0.05$).
 225

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

238
 239 **Table 7.** **SSC** (%) amounts of the grafted and ungrafted Paskal variety preserved 1 month after
 240 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																	
<table border="0" style="width:100%; text-align:center;"> <tr> <td></td> <td>Grafted/ungrafted</td> <td>Irrigated / Rainfed</td> <td>Grafted/ungrafted* Irrigated / Rainfed</td> <td></td> <td></td> </tr> <tr> <td>Prob>f</td> <td>0.2644</td> <td><.0001</td> <td>0.0012</td> <td></td> <td></td> </tr> </table>							Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed			Prob>f	0.2644	<.0001	0.0012		
	Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed														
Prob>f	0.2644	<.0001	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					
Prob>f	Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed		
	0.9949	0.0011	0.0096		

241 The mean values given in different capital letters in the same column and row and the mean values of the interaction
 242 in the middle of the table with lower case letters were statistically significant; those without lettering were found
 243 to be insignificant ($p < 0.05$).
 244

245 In the Paskal variety, one month after harvest, higher results were obtained in 2018 than those
 246 grafted in terms of TA (0.33%) and the highest value was obtained from those in rainfed
 247 conditions (0.34%), when compared with marketable fruits in irrigated and rainfed conditions
 248 on the land and preserved fruits. In the interaction between grafted and ungrafted, marketable
 249 fruits in irrigated and rained conditions in the field and preserved fruits, the highest value was
 250 obtained from the grafted Pascal variety (0.41%) under irrigated conditions and the lowest value
 251 was obtained from the ungrafted Pascal variety (0.22%) in irrigated conditions. In 2019, the
 252 difference between all applications was found to be statistically insignificant (Table 8).
 253
 254
 255
 256
 257

258 **Table 8.** TA(%) amounts of the grafted and ungrafted Paskal variety preserved 1 month after
 259 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					
Prob>f	Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed		
	<.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					
Prob>f	Grafted/ungrafted	Irrigated / Rainfed	Grafted/ungrafted* Irrigated / Rainfed		
	0.6357	0.1494	0.0904		

260 The mean values given in different capital letters in the same column and row and the mean values of the interaction
 261 in the middle of the table with lower case letters were statistically significant; those without lettering were found
 262 to be insignificant ($p < 0.05$).
 263

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

268 (6.30 and 6.43). In the interaction between grafted and ungrafted and marketable fruits in
 269 irrigated and rainfed conditions in the field and preserved fruits, the highest values were
 270 obtained from the preserved and ungrafted (6.41 and 6.65) Paskal variety (Table 9).

271
 272 **Table 9.** pH amounts of the grafted and ungrafted Paskal variety preserved 1 month after
 273 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		

274 The mean values given in different capital letters in the same column and row and the mean
 275 values of the interaction in the middle of the table with lower case letters were statistically
 276 significant; those without lettering were found to be insignificant ($p < 0.05$).
 277

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

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

285
 286 **Table 10.** SSC (%) amounts of the grafted and ungrafted Crimson Tide variety preserved 1
 287 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		

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

291
 292 There was no statistical difference in terms of TA in all applications in 2018, one month after
 293 harvest, in Crimson Tide variety. In 2019, the highest results were obtained from the grafted
 294 ones (0.25), and the highest values were obtained from the ones in irrigated conditions (0.27),
 295 when compared with the marketable fruits in the irrigated and rainfed conditions in the field
 296 and the preserved fruits. **The interactions in both years were insignificant** (Table 11).

297
 298 **Table 11.** TA(%) amounts of the grafted and ungrafted Crimson Tide variety preserved one
 299 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		

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

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

310
 311 **Table 12.** pH amounts of the grafted and ungrafted Crimson Tide variety preserved one month
 312 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				
Prob>f	Grafted/ungrafted 0.0271	Irrigated / Rainfed <.0001	Grafted/ungrafted* Irrigated / Rainfed <.0001	

313 The mean values given in different capital letters in the same column and row and the mean
314 values of the interaction in the middle of the table with lower case letters were statistically
315 significant; those without lettering were found to be insignificant ($p < 0.05$).
316

317 4. Conclusions

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

322 In the Crimson Tide variety included in the experiment, it was observed that the rate of
323 marketable fruits after one month was higher in the fruits of the plants in which grafting and
324 irrigation were applied to the irrigated and rainfed applications left in the field. **While there was**
325 **almost no marketable fruit in both years in Paskal variety with dark skin color, it was possible**
326 **to find marketable fruits in both years in Crimson Tide variety, although it varied according to**
327 **years. Selecting types with light colored rinds, which appear to be less susceptible to sunburn**
328 **than dark-rinded varieties, may help reduce the risk of sunburn injury (Maynard and Hopkins**
329 **(1999) and Shrefler et al. (2015).**

330 **SSC** is significantly affected by rootstocks in grafted production as well as by cultivars (Yetisir
331 and Sarı, 2003; Karaağaç, 2013, Çandır et al, 2013). Moreno et al. (2016) found significant
332 differences in **SSC** in grafted seeded watermelons, but they did not find a significant difference
333 in seeded watermelons. In some studies, decreases in **SSC** were also reported with grafting
334 (Alexopoulos and et al., 2007; Davis and Perkins-Veazie, 2008; Roupael et al., 2010;
335 **Kyriacou et al., 2018**). On the other hand, the positive effect of rootstock use on **SSC** was
336 reported by some researchers (Bekhradi et al., 2011; Mohamed et al., 2012; Gölükcü and
337 Tokgöz, 2018; Garcia-Lozano et al., 2019). The pH of watermelon fruit varies between 5.5 and
338 5.8 depending on maturity (Candır et al., 2013; Soteriou et al., 2014). The **SSC** regards to
339 findings of Özdemir et al. (2018) and Çandır et al. (2021) were similar to the results of this
340 study.

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

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

346 Similar to our study's findings, it was reported in various studies that TA content increases and
347 decreases in parallel with the changes in fruit juice pH during storage, and that there was a
348 higher TA content in grafted plants (Proietti et al., 2008; Çandır et al., 2013; Özdemir et al.,
349 2018; Çandır et al., 2021). Çandır et al. (2021) pH value of fruit juice Unlike our findings, it
350 was reported that the concentration decreased slightly during storage. But in this research,
351 grafted and ungrafted watermelons were analyzed for pH four times (0, 7, 14, and 21 days in
352 storage at 0°C) during storage. For this reason, since only the pH values 21 days after being put
353 into storage were more accurate, these results were similar to the results in the current study. **It**
354 **is reported that the postharvest behavior of apple fruit is affected by exposure to high sunlight**
355 **and temperature before harvest (Woolf and Ferguson, 2000; Rudell et al., 2008). According to**
356 **Bergh et al. (1980), sunlight diminishes the apple fruit's ability to be stored. Schrader et al,**
357 **(2009) found that SSC increased as the severity of sunburn browning increased in apples;**
358 **however, they reported that TA decreased markedly with more severe sunburn damage. Racsó**
359 **et al. (2009) reported that the level of sunburn damage varies according to apple cultivars.**

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

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

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

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

390 **Acknowledgements**

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

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