

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

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### ABSTRACT

Farmers have started to experience significant global production losses in watermelon, as in many crops, because of the increase in global warming. 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 was 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 both irrigated and rainfed conditions. The burn scale rates was high in ungrafted cultivars, but increased in rainfed cultivars. There was not much difference between the grafted and ungrafted varieties in terms of Soluble Solids Content (SSC) and Titratable Acidity (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 best way to avoid sunburn damage.

**Keywords:** *Citrullus lanatus*, Crimson tide variety, Grafted watermelon, Postharvest watermelon, Sunburn,

### INTRODUCTION

One of the most economically significant members of the Cucurbitaceae family is the watermelon (*Citrullus lanatus* (Thunb.) Matsum. and Nakai). World annual watermelon production is 101.6 million tons. China is the largest producer with 60.0 million tons of watermelon production. Turkey is the second largest watermelon producing country with 3.5 million tons. Other countries that produce the highest 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

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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 and 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 and 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 and 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 Turkey due to sunburn. This study was carried out at Alata Horticultural Research Institute Turkey, and was 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.

## MATERIALS AND METHODS

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 Gurdal 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 and 34° 20' 28.5 "E in 2018 and on April 11 in

**Table 1.** Soil analysis of the experimental site.

| Year | Analyzes                                    | Limit Values | Analysis Results (0-30 cm) |
|------|---------------------------------------------|--------------|----------------------------|
| 2018 | Texture (100 g mL <sup>-1</sup> )           | 30-50        | 38.00 (Loamy)              |
|      | Total Calcitic (CaCO <sub>3</sub> %)        | 5-15         | 35.40 (Highly calcareous)  |
|      | Salinity EC dS m <sup>-1</sup> (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 <sup>-1</sup> )  | 244-300      | 350.90 (High)              |
|      | Available phosphorus (mg kg <sup>-1</sup> ) | 20-40        | 29.80 (Optimum)            |
| 2019 | Texture (100 g/ml)                          | 30-50        | 40.00 (Loamy)              |
|      | Total Calcitic (CaCO <sub>3</sub> %)        | 5-15         | 32.30 (High calcareous)    |
|      | Salinity EC dS m <sup>-1</sup> (25°C)       | 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 <sup>-1</sup> )  | 244-300      | 647.70 (Very high)         |
|      | Available phosphorus (mg kg <sup>-1</sup> ) | 20-40        | 65.20 (High)               |

the area with coordinates 36° 37' 35.16" N and 34° 20' 28.51" E in 2019. The seedlings were planted with 2.5×0.7 m spacing and distances on the prepared banks with a width of 0.7 m and a height of 0.4 m, covered with black mulch.

xperiment 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 fertilizers were applied as pure substance as 140-160 kg Ha<sup>-1</sup> N, 80-100 kg Ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub>, 60-80 kg Ha<sup>-1</sup> K<sub>2</sub>O 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 at 4°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. 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.

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. In their study related to the increase in the severity of sunburn, Schrader *et al.* (2009) investigated the changes in SSC and TA, which are parameters affecting fruit core quality. 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 Soluble Solid Content (SSC, %), Titratable Acidity (TA, %) and pH levels of these fruits were investigated. Total SSC was measured by hand refractometer (Atago ATC-1E Model (Atago Co. Ltd., Tokyo, Japonya), TA by a potentiometric method (5 mL of the obtained fruit juice was taken, and the acidity value was measured with the help of the 0.1N NaOH solution), and the pH



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

reached 8.1. These measurements had no direct effect on quality-related sunburn but were made to give an idea of the consumer acceptability of sunburn and non-sunburn.

The climatic parameters of 2018 and 2019 during the research are given in Table 2.

### Statistical Analysis

Statistical evaluation of weighted averages of the scale values for each replication were calculated using the JMP 7.0 Package

**Table 2.** Climatic data of the trial area.

| Year | Climate Parameters                                    | April   | May     | June    | July    | August  |
|------|-------------------------------------------------------|---------|---------|---------|---------|---------|
| 2018 | Total global solar radiation (kWsaat/m <sup>2</sup> ) | 168.5   | 186.9   | 180.8   | 222.8   | 199.1   |
|      | Max. global solar radiation (watt m <sup>-2</sup> )   | 463 800 | 480 000 | 485 400 | 478 800 | 438 000 |
|      | Total global radiation (kW saat/m <sup>2</sup> )      | 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    |
| 2019 | Precipitation (mm= kg÷m <sup>2</sup> )                | 6.4     | 0.8     | 2.0     | 3.2     | 4.4     |
|      | Total global solar radiation (kWsaat/m <sup>2</sup> ) | 160.3   | 210.6   | 208.9   | 224.8   | 192.8   |
|      | Max. global solar radiation (watt m <sup>-2</sup> )   | 454 200 | 493 800 | 501 600 | 502 800 | 459 748 |
|      | Total global radiation (kWsaat/m <sup>2</sup> )       | 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÷m <sup>2</sup> )                 | 21.0    | 6.4     | 0.6     | 0.0     | 0.0     |

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.

## RESULTS AND DISCUSSION

In 2018, the ungrafted Paskal watermelon cultivar under irrigated conditions had 2.53 % scale 1, 16.35% scale 2, 11.35% scale 3, 34.30% scale 4, and 35.43% scale 5. 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).

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). Also, 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).

The burn rate of the ungrafted Crimson Tide watermelon variety under irrigated

**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 |

**Table 4.** Weighted Scale Averages of grafted and ungrafted Paskal variety, 1 month after harvest in 2018 and 2019 under irrigated and rainfed conditions.<sup>a</sup>

| 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<br>0.0011 | Irrigated/Rainfed<br>0.0006 | Grafted/Ungrafted×Irrigated/Rainfed<br>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<br>0.0067 | Irrigated/Rainfed<br>0.0025 | Grafted/Ungrafted×Irrigated/Rainfed<br>< 0.0001 |         |

<sup>a</sup> 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 ( $P < 0.05$ ).

conditions in 2018, scale 1 was 3.60%, scale 2 was 11.48%, scale 3 was 23.00%, scale 4 was 30.95%, and 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%, and 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, and 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%, and 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%, and 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).

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, the 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 the rainfed (3.87). The interactions in both years were insignificant (Table 6).

Fruit samples were taken from grafted and ungrafted Paskal and Crimson Tide varieties 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 their SSC, TA, and pH were examined. In the Paskal variety,

**Table 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 |

**Table 6.** Weighted Scale Averages of grafted and ungrafted Crimson Tide variety 1 month after harvest in 2018 and 2019 under irrigated and rainfed conditions.<sup>a</sup>

| 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<br>0.3164   | Irrigated/Rainfed<br>< 0.0001 | Grafted/Ungrafted×Irrigated/Rainfed<br>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<br>< 0.0001 | Irrigated/Rainfed<br>< 0.0001 | Grafted/Ungrafted×Irrigated/Rainfed<br>0.7389 |         |

<sup>a</sup> 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 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 rainfed 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).

In 2018, one month after harvest, TA results (0.33%) of Paskal variety were

higher than those grafted and, compared with marketable fruits in irrigated and rainfed conditions, the highest value was obtained in rainfed conditions (0.34%). In the interaction between grafted and ungrafted, marketable fruits in irrigated and rainfed 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).

In 2018, one month after the harvest, pH in grafted Paskal variety did not have a statistical effect, while the highest value was



**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.<sup>a</sup>

| 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 |                   |                   |                                     |          |         |
|               | 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 |                   |                   |                                     |          |         |
|               | Grafted/Ungrafted | Irrigated/Rainfed | Grafted/Ungrafted×Irrigated/Rainfed |          |         |
| Prob> f       | 0.9949            | 0.0011            | 0.0096                              |          |         |

<sup>a</sup> 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 ( $P < 0.05$ ).

**Table 8.** TA (%) of the grafted and ungrafted Paskal variety preserved 1 month after harvest, in irrigated and rainfed conditions.<sup>a</sup>

| 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                              |         |         |

<sup>a</sup> 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 ( $P < 0.05$ ).

obtained from the ungrafted in 2019. When compared in terms of marketable fruits in irrigated and rainfed conditions 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).

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



**Table 9.** pH of the grafted and ungrafted Paskal variety preserved 1 month after harvest, in irrigated and rainfed conditions.<sup>a</sup>

| 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<br>0.7695   | Irrigated/Rainfed<br><.0001   | Grafted/Ungrafted×Irrigated/Rainfed<br>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<br>< 0.0001 | Irrigated/Rainfed<br>< 0.0001 | Grafted/Ungrafted×Irrigated/Rainfed<br>< 0.0001 |         |         |

<sup>a</sup> 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 ( $P < 0.05$ ).

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 case of grafted and ungrafted and marketable fruits in irrigated and rainfed conditions in the field and preserved fruits, interaction was insignificant in 2018. But interaction was significant in 2019 because it was taken from the irrigated and ungrafted Crimson Tide variety (8.40%) (Table 10).

In 2018, one month after harvest, Crimson Tide had no statistical difference in terms of TA in all applications. 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).

In the Crimson Tide variety stored until one month after harvest, the pH difference was found to be statistically significant in those grafted in 2018 (5.95) and those not grafted in 2019 (6.57). 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) had the highest values. In grafted and ungrafted

marketable fruits in irrigated and rainfed conditions in the field and preserved fruits, the interaction was insignificant in 2018. In 2019, ungrafted and preserved fruits (7.36) were found to be statistically significant (Table 12).

## 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, and there were almost no marketable fruits in the fruits of grafted and ungrafted in all applications of Paskal variety.

In the Crimson Tide variety, it was observed that, after one month, the rate of marketable fruits (Burn Scale Rates 1) 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

**Table 10.** Soluble Solid Content (%) of the grafted and ungrafted Crimson Tide variety preserved 1 month after harvest, in irrigated and rainfed conditions.<sup>a</sup>

| 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<br>0.0016 | Irrigated / Rainfed<br><.0001 | Grafted/ungrafted×Irrigated/Rainfed<br>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<br>0.5517 | Irrigated/Rainfed<br>0.0773   | Grafted/Ungrafted×Irrigated/Rainfed<br>0.0049 |         |         |

<sup>a</sup> 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).

**Table 11.** TA (%) of the grafted and ungrafted Crimson Tide variety preserved one month after harvest, in irrigated and rainfed conditions.<sup>a</sup>

| 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<br>0.0822   | Irrigated/Rainfed<br>0.7621   | Grafted/Ungrafted×Irrigated/Rainfed<br>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<br>< 0.0001 | Irrigated/Rainfed<br>< 0.0001 | Grafted/Ungrafted×Irrigated/Rainfed<br>0.3341 |         |         |

<sup>a</sup> 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).

**Table 12.** pH of the grafted and ungrafted Crimson Tide variety preserved one month after harvest, in irrigated and rainfed conditions.<sup>a</sup>

| 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<br>< 0.0001 | Irrigated/Rainfed<br>0.0012   | Grafted/ungrafted×Irrigated/Rainfed<br>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<br>0.0271   | Irrigated/Rainfed<br>< 0.0001 | Grafted/ungrafted×Irrigated/Rainfed<br>< 0.0001 |         |         |

<sup>a</sup> 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).

varieties, may help reduce the risk of sunburn injury (Maynard and Hopkins, 1999; 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 *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 (Çandır *et al.*, 2013; Soteriou *et al.*, 2014). The SSC 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). Unlike our findings, Çandır *et al.* (2021) reported that pH value of fruit juice concentration decreased slightly during storage. However, 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 of 21-days 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 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. Since the product is put on the market in April-May, sunburn does not occur in this period, i.e both the air temperature and sunbathing are not at a level to cause sunburn. In the cultivation that takes place in open field conditions, fruit is offered to the market in May-June. In case of good irrigation and fertilization, there is no, or very low, risk of sunburn on fruits (very large fruit varieties). If producers do not provide these good growing conditions, losses may occur due to sunburn over the years. 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, 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 Turkey 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 if earliness, plant structure, grafted or non-grafted, irrigation, and maintenance conditions are adjusted well.

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. In terms of TA (%), it was observed that there was not much difference between grafted and ungrafted with preserved, irrigated, and rainfed applications. The pH 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.

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## بررسی آفتاب سوختگی ارقام هندوانه با رنگ های مختلف در شرایط آبیاری و دیم

### و. ارس

### چکیده

اخیراً، در تولید جهانی هندوانه و بسیاری از محصولات دیگر تلفات قابل توجهی به کشاورزان آغاز شده است که دلیل آن افزایش گرمایش جهانی است. برای تحقیق در مورد آفتاب سوختگی در هندوانه، پژوهشی در سال‌های ۲۰۱۸ و ۲۰۱۹ با استفاده از هندوانه راه راه، کریمسون تاید (Crimson Tide) پیوند نشده بر روی ارقام هیبریدی Nun9075 و پاسکال (Paskal) با رنگ زمینه سبز تیره، ونیز پیوند نشده و پیوندی روی رقم گوردال (Gürdal)، در مزرعه انجام شد. زمانی که دهلیزها و زالوها خشک شده بودند، زمان برداشت تعیین شد. در زمان برداشت، نمونه‌هایی تهیه و نگهداری شد. پس از این تاریخ‌ها، نیمی از آزمایش آبیاری شد، در حالی که نیمی دیگر دیم بود و برای یک ماه دیگر ادامه یافت. برداشت در هر کرت یک ماه بعد انجام شد و میزان آفتاب سوختگی در هر کرت با استفاده از مقیاس ۱-۵ که ایجاد کردیم ارزیابی شد. در وارپته پاسکال که رنگ پوست آن در هر دو سال سیاه بود، آفتاب سوختگی زودتر شروع شد و پس از گذشت یک ماه در شرایط آبی و دیم، تقریباً هیچ میوه قابل عرضه به بازار روی گیاهان باقی نماند. مقدار مقیاس سوختگی در ارقام

پیوند نشده بالا بود، اما در ارقام دیم افزایش یافت. تفاوت زیادی بین ارقام پیوندی و پیوند نشده از نظر محتوای جامدات محلول (SSC) و اسیدیته قابل تیتراسیون (TA) (%) وجود نداشت. توصیه می شود که از نهال های پیوندی و ادامه آبیاری در مکان هایی که ممکن است آفتاب سوختگی داشته باشد استفاده شود. با این حال، ایجاد شرایط مساعد برای رشد قوی بوته که میوه هندوانه را سایه می اندازد، بهترین راه برای جلوگیری از آسیب آفتاب سوختگی است.