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Journal of Agricultural Sciences
Journal homepage:
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Rootstocks Affected Postharvest Performance of Grafted 'Crisby' and 'Crimson Tide' Watermelon Cultivars

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ARTICLE INFO
Research Article DOI:10.15832/ankutbd.345469
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Received: 20 October 2017, Received in Revised Form: 23 January 2018, Accepted: 20 February 2018

ABSTRACT

Watermelon fruit from 'Crisby' (CR) and 'Crimson Tide' (CT) grafted onto Ferro, RS841, Argentario and Macis rootstocks and non-grafted CR and CT were compared for their postharvest quality at 7 °C for 21 days. Changes in rind thickness, weight loss, fruit flesh firmness, taste, total soluble solids, juice pH, titratable acidity, chilling injury and fungal decay, flesh color values, hallow heart, ripening, citric and malic acid, glucose, fructose, sucrose, total sugar, β-carotene and lycopene were determined during storage at a weekly interval. Watermelon fruit cv. CT grafted on Ferro, RS841 and Argentario rootstocks had thicker rind, lower ripening score, higher flesh firmness and lycopene content, more intense red color during storage, compared to non-grafted fruit. In comparison to non-grafted fruit, CR fruit grafted on Ferro, RS841 and Argentario rootstocks had thicker rind and higher flesh firmness, but higher lycopene content and C* values with lower ripening scores were observed only in the fruit grafted on Ferro and RS841 rootstocks. Macis and Argentario may lead an over-ripening, softening and less intense flesh color with lower lycopene content for CR and/or CT fruit during storage. Watermelons could successfully be kept for 21 days at 7 °C. Watermelons grafted on Ferro and RS841 rootstocks retained better postharvest quality, compared to the non-grafted fruit for both cultivars.

Keywords: Watermelon; Grafting; Rootstock; Storage; Quality

1. Introduction

Watermelon is widely grown crop in almost all regions of Turkey and many areas of the world. Soil borne diseases cause a decrease in yield and quality. Use of soil-borne disease resistant rootstocks such as *Cucurbita* and *Lagenaria* was suggested as an environmentally safe alternative to methyl bromide (Miguel et al 2004).

Bottle gourd, interspecific hybrids between C. *maxima* and C. *moschata*, and wild watermelon (*Citrullus lanatus* var. Citroides) are the most common rootstocks for watermelon (Davis et al 2008). Effects of grafting on watermelon quality were reported previously at harvest (Yetişir & Sarı 2003; Yetişir et al 2003; Davis & Perkins-Veazie 2005; Çandır et al 2013). These effects varied

depending upon production environments, type of rootstock, interactions between specific rootstocks and scions, and harvest date (Davis et al 2008). The recommendation conditions for short-term storage or transport to distant markets (>7 days) are 7.2 °C (45 °F) temperature and 85-90% relative humidity (RH) conditions to maintain postharvest quality of watermelons (Suslow 1997). However, watermelons in most of the world are shipped and stored for short-term under non-refrigerated conditions in practice (Chisholm & Picha 1986; Perkins-Veazie & Collins 2006; Radulovic´ et al 2007). This practice leads quality loss in watermelon. There are few reports on the effects of grafting on storage and shelf life of watermelons. In our previous studies, the postharvest quality of 'Crisby' and 'Crimson Tide' watermelon cultivars grafted on Ferro, RS841, Argentario and Macis rootstocks were determined at 21 °C and 70±5% relative humidity for 7 days after 21 days of cold storage (Özdemir et al 2016) and in common marketing condition at 27 °C (Chisholm & Picha 1986) and 50±5% relative humidity for 7 days and at 21 °C and 70±5% relative humidity for 7 days after 21 days of cold storage (Aras et al 2015). It was reported that firmer fruit at harvest are more likely to maintain a desirable consistency during postharvest period and are expected to have a better shelf life than are softer fruit (Roberts et al 2007; King et al 2010). Therefore, effects of grafting on storage performance of watermelon fruit have gained importance. Our objective in this experiment was to determine effects of the commercial rootstock(s) on the postharvest performance of grafted 'Crisby' and 'Crimson Tide' watermelon cultivars.

2. Material and Methods

The rootstocks tested in this study are Ferro, RS841 (*Cucurbita maxima* x *C. moschata*) and Argentario and Macis (*Lagenaria siceraria*). 'Crisby' (CR) and 'Crimson Tide' (CT) watermelon [*Citrullus lanatus* (Thunb.) Matsum. and Nakai] cultivars were used as scion. Grafted and non-grafted (control) seedlings were obtained by a commercial seedling company (Grow Fide, Antalya/Turkey). Plants were grafted by one cotyledon grafting technique. The experiment was carried out in the Alata Horticultural Research Institute, Erdemli, Mersin, Turkey. The grafted plants were planted under low tunnel in early spring and regular cultural practices for watermelon were applied.

Fruit were harvested at full maturity when the 75% of tendril and stipule on the same node with peduncle were dried (Özdemir et al 2014). After harvest, fruit were stored at 7±0.5 ºC and 90±5% relative humidity for 21 days. The analyses were done during storage at a 7-day interval. Fruit was cut longitudinally and rind thickness (mm) was measured using an electronic caliper at two points on cross-section of each fruit. The thirty fruits were numbered and the weight loss (%) was calculated by subtracting the final weigh from the initial weigh in percent. The fruit showing chilling injury symptoms (CI) and decay (1= none, 2= <10% of surface area, 3= 11% to 25%, 4= 26% to 50%, and 5= > 50%) were determined according to Risse et al (1990). Fruit flesh firmness was measured using a penetrometer with 12 mm of conic probe (Now FHR-5 Nippon Optical Works Co. Ltd. Tokyo, Japan) at the three points on the mesocarp tissue of the watermelon fruit heart portion and expressed as Newton (N). Fruit was sliced and its rind and seeds were removed and then total soluble solids (TSS) content (%) was assessed in the juice obtained from 5 fruit per replicate with a digital refractometer (Atago Model ATC-1E Atago Co. Ltd., Tokyo, Japan) at 20 °C. Juice pH was measured by digital pH-meter (Orion 5-Star model Thermo Fisher Scientific Inc., MA, ABD). Titratable acidity (TA) was determined by titration of 5 mL of juice with 0.1 N NaOH to a pH of 8.1, and it was expressed as percent of malic acid equivalents. Taste (1-9) of fruit were rated on hedonic scale of 1= disliked (the lowest value) to 9= liked (the best) by a trained panel consisting of 10 people (non-smoker 7 male and 3 female, ages 20 to 45). The taste scores >5 were considered as acceptable quality. Hallow heart (1-5) of fruit were rated on a scale of 1= none to 5= very severe (50% "more than hallow heart) and ripening (1-7) of fruit were rated on a scale of 1= raw fruit and 3= mature to 7= over-ripe extremely by trained ten panelists. Fruit flesh color (L* C* h°) was measured using the CIELAB (L* a* b*) color

space by a CR-300 Minolta Chroma Meter (Konica Minolta, Osaka, Japan) on the two points of the mesocarp tissue of the watermelon fruit heart portion. Sugars (sucrose, glucose and fructose) and organic acids (malic and citric acid) were extracted according to the method described by Çandır et al (2013). The results were expressed as g 100 g^{-1} fresh weight. Carotenoids were extracted by the method described by Perkins-Veazie & Collins (2006). Detection was carried out at 503 nm for lycopene and 452 nm for β-carotene using the PDA detector in the HPLC. The lycopene and β-carotene contents were expressed as μg g^{-1} fresh weight. The study was performed over a 2-year period. Data are represented as the mean of two experimental years. The data were analyzed a completely randomized block design by ANOVA using SAS software of SAS Institute, Cary, N.C. (SAS 2017). The data were obtained from three replications per scion/rootstock combination. Each replicates contained 5 fruit. Mean separation was performed by Fisher's Least Significance Test at $P<0.05$ level.

3. Results and Discussion

At harvest, CT fruit from grafted plants had thicker rind than those from non-grafted plants while grafting did not affect rind thickness for CR cultivar. Rind thickness decreased in non-grafted and at a lesser extent in grafted fruit during storage period in both cultivars, except for RS-841 rootstock. RS-841 rootstock for both cultivars showed similar rind thickness after 21 days storage to initial values. Fruit grafted on RS841, Argentario and Ferro rootstocks had thicker rind compared to non-grafted fruit during storage for both cultivars (Figure 1). Thinning of the rind may indicate an overripe fruit or fruit subjected to prolonged storage (Kyriacou & Soteriou 2015). Rind thickness of CR cultivar grafted on TZ-148, RS-841 and 64-18 of *Lagenaria* rootstock was similar to non-grafted controls (Alan et al 2007). Davis et al (2008) also found rind thickness increased for both seedless and seeded watermelon fruit when grafted to gourd rootstock '451'. In the study with 'Crimson Tide' cultivar, all of the grafted plants on bottle gourd rootstocks produced fruit with a thicker rind than the control plants (Karaca et al 2012).

Weight loss in grafted and non-grafted fruit were very low (<1%) during storage for both cultivars. Effect of rootstocks on weight loss was not significant during storage period in both cultivars (Figure 2). Consistent with our results, Perkins-Veazie & Collins (2006) reported the <1% of weight loss in watermelon fruit at all temperatures (5 °C, 13 °C and 21 °C) after 14 days of storage. However, Neto et al (2000) determined higher weight loss (3.8%) than our results. Suárez-Hernández et al (2016) reported that the some rootstocks caused to reduce in weight loss during a storage period of 14 days at 15 to 17 °C and 80% RH conditions.

Non-grafted or grafted watermelons onto different rootstocks did not exhibit CI symptoms

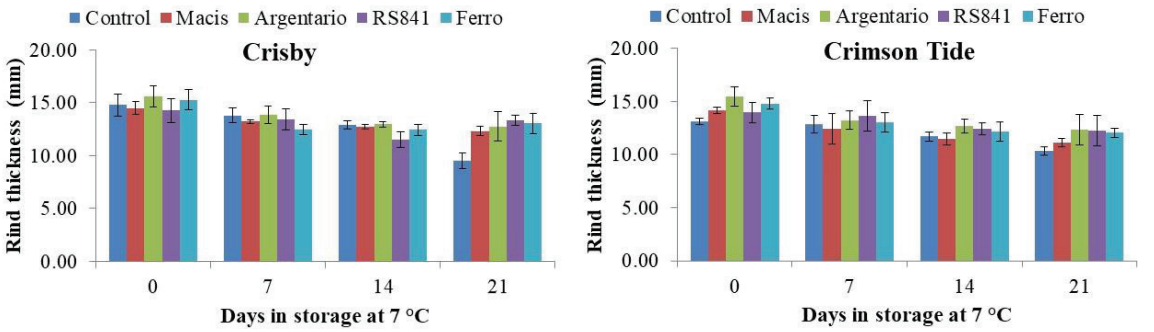

Figure 1- Effects of rootstocks on rind thickness of 'Crisby' and 'Crimson Tide' watermelon fruit during storage at 7 °C

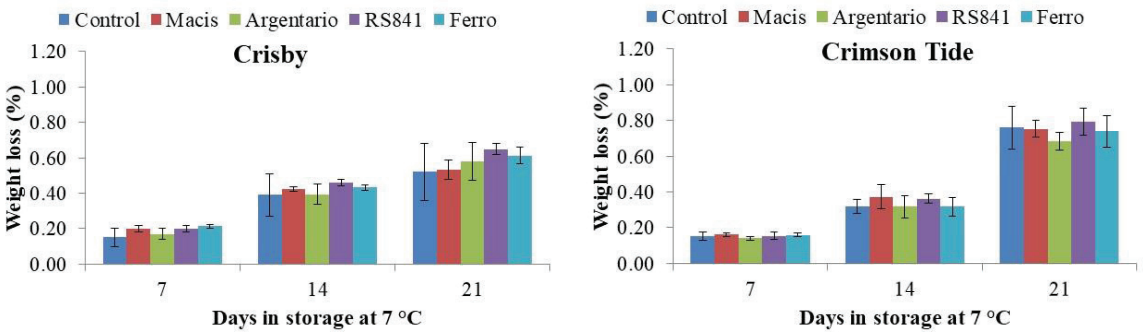

Figure 2- Effects of rootstocks on weight loss of 'Crisby' and 'Crimson Tide' watermelon fruit during storage at 7 °C

during storage period. Fungal decay was not observed on non-grafted and grafted fruit of both cultivars during storage at 7 °C.

Flesh firmness decreased during storage for both cultivars (Data not presented). Watermelons grafted on Ferro (6.98-7.19 N) and RS841 (6.78-7.19 N) rootstocks had the higher flesh firmness for both cultivars (Table 1 and 2), compared to other rootstocks (6.29-6.52 N for Argentario, 5.89-6.23 N for Macis) and control (5.44-5.59 N) after 21 days of storage. Consistent with our study, flesh firmness of watermelon fruit cv. 'Sugar Baby', 'Baby Fun' and 'Minilee' decreased during storage during 4 weeks of storage at 5°, 10°, 15° or 20 °C (Risse et al 1990). At harvest, an increase in flesh firmness due to grafting has been reported (Yetişir et al 2003; Davis & Perkins-Veazie 2005; Roberts et al 2007; Cushman & Huan 2008; Bruton et al 2009; Soteriou & Kyriacou 2015) while grafting on some rootstocks seems not affect watermelon firmness (Karaca et al 2012). The findings of Kyriacou & Soteriou (2015) indicated that *C. maxima* × *C. moschata* hybrids maintained firmness better, compared with non-grafted controls. Authors also reported a greater effect of rootstocks on firmness, in comparison to effects of cultivar and storage period. Suárez-Hernández et al (2016) reported that the some rootstocks retained firmness better than control during storage.

TSS content remained above 10% in fruit of both cultivars throughout storage period (Table 1 and 2), rendering fruit acceptable for perceived sweetness as reported by Kyriacou & Soteriou (2015). In CR cultivar, fruit grafted on Ferro and RS-841 rootstock had higher TSS content after storage period for 21 days at 7 °C, compared to other graft combinations and control (Table 1). In case of CT cultivar, control had higher TSS content than some of the graft combinations after 14 days, but control and grafted fruit had similar TSS content after 7 or 21 days (Table 2). Although some previous studies showed that grafting had no effect on TSS (Miguel et al 2004; Proietti et al 2008; Bruton et al 2009; Bekhradi et al 2011; Soteriou & Kyriacou 2015), grafting on the bottle gourd rootstocks increased TSS contents of watermelons compared to the control fruit in some reports (Karaca et al 2012; Çandır et al 2013; Suárez-Hernández et al 2016). In other studies, grafted watermelons had lower TSS content compared to non-grafted controls (Davis & Perkins-Veazie 2005; Roberts et al 2007; Kyriacou & Soteriou 2015). Our reports are consistent with the previous studies, indicating effects of rootstocks on TSS content, cultivar depending.

Juice pH value slightly decreased during storage (Data not presented). Similarly, lower pH values were reported in 'Charleston Gray' watermelons fruit after a storage period of 14-19 days at 7 °C (Chisholm & Picha 1986). In CR cultivar, non-grafted fruit had higher pH comparing to grafted

fruit after 21 days of storage. In CT cultivar, fruit on RS841 rootstocks resulted in lower pH than those on other rootstocks and non-grafted fruit after 21 days of storage (Table 1 and 2). In agreement with our findings, grafted CT watermelons on some local bottle gourd rootstocks had lower juice pH, compared to control (Çandır et al 2013).

TA content slightly increased in parallel with changes in juice pH during storage for both cultivars (Data not presented). In CR cultivar, there was no significant difference in TA between non-grafted and grafted fruit during storage (Table 1). In CT cultivar, fruit on RS841 rootstock resulted in higher TA than those on other rootstocks and non-grafted fruit after 21 days of storage (Table 2). Higher TA due to grafting was reported in watermelon fruit (Proietti et al 2008; Çandır et al 2013). The malic acid content varied from 0.19% to 0.42% for CR cultivar and 0.19% to %0.65 for CT cultivar (Table 1 and 2) and the citric acid content varied from 0.08% to 0.09% for CR cultivar and 0.10% to 0.14% for CT cultivar during storage (Data not presented). Malic acid was the predominant organic acid for both cultivars. CR fruit on RS841 rootstock had higher malic acid content than other graft combinations and control after 21 days of storage. Although CT fruit non-grafted or grafted on Macis had lower malic acid content at harvest, non-grafted or grafted CT fruit had similar malic acid content during storage. The citric acid content was not affected by grafting during storage for both cultivars (Data not presented).

Flesh color lightness (L* value) decreased during storage for both cultivars (Data not shown). Similarly Perkins-Veazie & Collins (2006) determined lower L* values in the fruit after 14 days of storage at 21 °C, compared freshly harvested watermelons. Grafting did not affect flesh color lightness during storage for both cultivars. In contrast to our findings, Kyriacou & Soteriou (2015) reported that flesh color lightness (L*) of watermelon fruit was affected by rootstock and storage and all hybrid rootstocks invariably maintained darker flesh color during storage. In CT cultivar, C* value peaked after 7 days and then decreased during storage (Data not shown). In CR cultivar, C* value showed gradual decrease toward the end of storage (Data not presented). In CR fruit, grafting did not affected the C* values, but CT fruit grafted on RS841, Argentario and Ferro rootstocks had more intense (higher C*) color than those on Macis and control fruit during storage. The h° values showed a progressive increase in non-grafted fruit with a lesser extent in grafted fruit during storage in both cultivars (Table 1 and 2). This indicated a change of flesh color from red to orange-yellow. These changes in h° value indicate over-ripening and senescence of watermelons which are subjected to prolonged storage (Kyriacou & Soteriou 2015). In CR cultivar, non-grafted fruit had higher h° values than grafted fruits after 14 days of storage, but non-grafted and grafted fruit had similar h° values after 21 days of storage (Table 1). In CT cultivar, non-grafted fruit had higher h° values than grafted fruit after 7 and 14 days, but non-grafted fruit and fruit on Macis had higher h° values than others after 21 days of storage (Table 2). Lycopene content in both cultivars showed similar trend with C* values (Table 1 and 2). Lycopene content significantly decreased at the end of storage for CR cultivar, but peaked after 7 days and then decreased during storage for CT cultivar (Data not presented). In CR cultivar, all grafted fruit had higher lycopene content at harvest, compared to non-grafted fruit, but similar lycopene content was determined among non-grafted and grafted fruit after 21 days of storage (Table 1). In CT cultivar, fruit grafted on RS841, Argentario and Ferro rootstocks had higher lycopene content than those on Macis and non-grafted fruit after 21 days of storage (Table 2). Postharvest color changes and lycopene biosynthesis in watermelons can be affected by storage temperature and cultivar. Perkins-Veazie & Collins (2006) reported that watermelons stored at 21 °C had higher C* value and lycopene content, compared to initial value at harvest whereas no or little change was observed in C* value and lycopene content of fruit held at 5 °C or 13 °C depending on cultivars. Consistent with our results, previous studies have typically shown higher lycopene content in watermelon fruit from grafted plants at harvest (Davis & Perkins-Veazie 2005; Davis et al 2008; Proietti et al 2008;

Table 1- Effects of rootstocks on some quality attributes of 'Crisby' watermelon fruit during storage at 7 °C

Quality parameters	*Scion/rootstock*	*Days in storage at 7 °C*			
		0	*7*	*14*	*21*
Firmness (N)	CR (Control)	7.84 b[x]	6.93 c	5.77 d	5.59 b
	CR/Macis	7.57 c	7.37 bc	6.65 c	5.89 b
	CR/Argentario	8.13 a	7.43 b	7.21 bc	6.29 b
	CR/RS841	8.26 a	8.50 a	8.20 a	7.19 a
	CR/Ferro	8.24 a	8.47 a	7.38 b	7.19 a
TSS (%)	CR (Control)	10.32 a	10.93 a	10.77 a	10.37 b
	CR/Macis	10.20 a	10.57 a	10.63 a	10.53 b
	CR/Argentario	10.57 a	10.77 a	10.90 a	10.46 b
	CR/RS841	10.30 a	10.57 a	10.97 a	11.03 a
	CR/Ferro	10.97 a	10.90 a	11.12 a	11.17 a
Juice pH	CR (Control)	5.65 a	5.46 a	5.55 a	5.51 a
	CR/Macis	5.65 a	5.48 a	5.44 b	5.41 b
	CR/Argentario	5.67 a	5.54 a	5.43 b	5.33 b
	CR/RS841	5.58 a	5.50 a	5.47 b	5.34 b
	CR/Ferro	5.54 a	5.50 a	5.35 c	5.39 b
Malic acid (%)	CR (Control)	0.25 a	0.28 a	0.22 b	0.31b
	CR/Macis	0.24 ab	0.27 a	0.26 ab	0.32b
	CR/Argentario	0.19 c	0.29 a	0.22 b	0.29b
	CR/RS841	0.23 b	0.31 a	0.29 a	0.42a
	CR/Ferro	0.24 ab	0.31 a	0.26 ab	0.32b
h°	CR (Control)	38.17 a	46.55 a	47.73 a	48.88 a
	CR/Macis	35.86 b	45.81 a	43.98 b	46.09 a
	CR/Argentario	36.76 b	44.85 b	44.72 b	47.56 a
	CR/RS841	35.47 b	43.10 c	45.19 b	48.80 a
	CR/Ferro	35.92 b	44.68 b	45.98 b	49.03 a
Lycopene (μg g^{-1})	CR (Control)	38.30 c	31.94 b	25.18 b	26.17 a
	CR/Macis	46.25 a	35.75 b	29.17 ab	28.18 a
	CR/Argentario	41.71 bc	38.90 ab	29.92 ab	24.51 a
	CR/RS841	44.16 ab	45.56 a	31.14 a	27.43 a
	CR/Ferro	44.22 ab	40.38 ab	27.52 ab	26.14 a
Ripening (1-7)	CR (Control)	3.67 a	3.86 a	3.50 a	3.43 b
	CR/Macis	3.17 b	3.52 a	3.40 a	3.53 b
	CR/Argentario	3.59 a	3.72 a	3.70 a	3.93 a
	CR/RS841	3.08 b	3.20 a	3.33 a	3.23 c
	CR/Ferro	3.19 b	3.20 a	3.33 a	3.53 b
Taste (1-9)	CR (Control)	8.29 a	8.11 a	7.19 b	6.34 c
	CR/Macis	8.41 a	8.24 a	7.55 ab	6.81 b
	CR/Argentario	8.03 a	8.19 a	8.02 a	6.67 b
	CR/RS841	8.19 a	8.30 a	7.89 a	7.20 a
	CR/Ferro	8.25 a	8.39 a	7.84 a	6.94 ab

[x], mean separation was performed by Fisher's LSD test. Means (n= 3) followed by same letters within a column are not significantly different at $P<0.05$

Table 2- Effects of rootstocks on some quality attributes of 'Crimson Tide' watermelon fruit during storage at 7 °C

Quality parameters	*Scion/rootstock*	*Days in storage at 7 °C*			
		0	*7*	*14*	*21*
Firmness (N)	CT (Control)	7.37 c[x]	6.02 c	6.10 c	5.44 c
	CT/Macis	7.75 bc	6.06 c	6.44 c	6.23 b
	CT/Argentario	7.96 b	6.88 b	6.75 bc	6.52 b
	CT/RS841	8.31 ab	7.81 a	7.29 ab	6.78 a
	CT/Ferro	8.55 a	8.17 a	7.65 a	6.98 a
TSS (%)	CT (Control)	11.13 a	11.13 a	11.30 a	11.03 a
	CT/Macis	10.63 a	10.83 a	10.67 b	10.63 a
	CT/Argentario	10.80 a	10.83 a	10.57 b	11.03 a
	CT/RS841	10.87 a	11.07 a	10.97 ab	11.00 a
	CT/Ferro	10.57 a	10.93 a	11.13 a	10.50 a
Juice pH	CT (Control)	5.67 a	5.52 a	5.50 a	5.43 a
	CT/Macis	5.66 a	5.50 a	5.37 b	5.41 a
	CT/Argentario	5.69 a	5.47 a	5.37 b	5.36 a
	CT/RS841	5.66 a	5.43 a	5.30 c	5.27 b
	CT/Ferro	5.56 a	5.48 a	5.37 b	5.40 a
Malic acid (%)	CT (Control)	0.23 c	0.22 ab	0.25 b	0.48 a
	CT/Macis	0.21 c	0.19 b	0.29 a	0.47 a
	CT/Argentario	0.27 b	0.23 ab	0.26 b	0.58 a
	CT/RS841	0.30 a	0.26 a	0.27 ab	0.65 a
	CT/Ferro	0.32 a	0.27 a	0.26 b	0.52 a
h°	CT (Control)	40.82 a	44.84 a	44.19 a	48.75 a
	CT/Macis	40.84 a	43.17 b	43.34 b	48.29 a
	CT/Argentario	39.21 b	42.53 bc	43.13 bc	44.89 b
	CT/RS841	39.63 b	41.10 d	41.52 d	44.65 b
	CT/Ferro	39.42 b	41.37 cd	42.60 c	44.50 b
Lycopene (μg g^{-1})	CT (Control)	34.53 c	38.92 c	24.26 b	33.11 bc
	CT/Macis	33.08 c	42.17 bc	38.73 a	29.71 c
	CT/Argentario	55.10 a	46.20 b	35.23 a	42.46 a
	CT/RS841	45.05 b	47.14 ab	34.67 a	42.84 a
	CT/Ferro	46.89 b	52.52 a	41.11 a	43.57 a
Ripening (1-7)	CT (Control)	3.32 a	4.29 a	4.33 a	4.50 a
	CT/Macis	3.31 a	3.63 b	3.67 b	4.13 b
	CT/Argentario	3.18 a	3.42 bc	3.54 b	3.92 b
	CT/RS841	3.13 a	3.19 c	3.63 b	4.07 b
	CT/Ferro	3.13 a	3.13 c	3.38 b	3.96 b
Taste (1-9)	CT (Control)	8.16 ab	8.44 b	7.63 a	7.06 c
	CT/Macis	7.87 b	8.34 b	7.90 a	7.41 c
	CT/Argentario	8.46 a	8.48 a	8.03 a	7.86 ab
	CT/RS841	8.41 a	8.32 b	7.82 a	7.75 ab
	CT/Ferro	8.44 a	8.85 a	8.08 a	8.05 a

[x], mean separation was performed by Fisher's LSD test. Means (n= 3) followed by same letters within a column are not significantly different at P<0.05

Çandır et al 2013) and during storage (Kyriacou & Soteriou 2015). The increase in C* value of watermelon fruit was probably as a result of the increase in lycopene content (Perkins-Veazie & Collins (2006). Degradation in lycopene during senescence of non-grafted watermelon fruit of both cultivar and grafted CR fruit after prolonged storage and consequent shelf life period led to decrease in C* value and increase in h° value. Flesh color changes was observed in non-grafted fruit, suggesting that fruit ripening occurs faster in non-grafted than in grafted fruit during storage.

β-carotene content was not significantly changed and was not affected by grafting during storage (data not presented). In our study, lower storage temperature may suppress increase in β-carotene content. In agreement with our results, a similar β-carotene content was reported between fruit grafted on some local bottle gourd rootstocks and non-grafted fruit (Çandır et al 2013).

We found a slight increase in ripening ratings during storage for both cultivars (Data not presented), indicating fruit became overripe toward the end of storage. Similar findings were reported by Risse et al (1990) for several watermelon cultivars during 4 weeks of storage at 5, 10, 15 or 20 °C. In CR cultivar, fruit grafted on RS841 rootstock had lower ripening scores than those from other rootstocks and control fruit after 21 days of storage (Table 1). In CT cultivars all grafted fruit had lower ripening scores, compared to non-grafted fruit after 21 days of storage (Table 2). Ripening could be retarded by grafting in watermelon fruit at harvest. Soteriou et al (2014) found that as grafting retarded the ripening process, optimum harvest maturity in non-grafted plant was reached at 35-40 days post-anthesis (dpa) compared with 40-45 dpa in grafted plants.

Effects of grafting on hallow heart was not significant during storage for both cultivars (data not shown). Cushman & Huan (2008) found higher incidence of hollow heart in non-grafted watermelon plants than in those grafted. However, the environmental and cultural conditions affect incidence of hollow heart beside to rootstocks.

In CR cultivar, effect of grafting on total and individual sugar contents was not significant during storage (data not shown). In CT cultivar, although sucrose and total sugar contents were not affected by grafting, fructose and glucose content were higher in fruit grafted on RS841, Ferro and Argentario rootstocks than those on Macis and non-grafted fruit after 7 days of storage at 7 °C (data not shown). The differences in fructose and glucose contents between grafted and non-grafted fruit disappeared afterwards. Lower sugar content was reported in grafted watermelon fruit than non-grafted fruit in some studies (Yetişir et al 2003; Davis & Perkins-Veazie 2005; Roberts et al 2007). In contrast, other studies showed similar sugar contents in grafted and non-grafted watermelon fruit (Miguel et al 2004; Proietti et al 2008; Bruton et al 2009; Bekhradi et al 2011). In agreement with our results, Kyriacou & Soteriou (2015) found no significant effect of the hybrid rootstocks on sucrose concentration of watermelon. Previous study have shown that increasing fructose, glucose, and sucrose contents of CT watermelon fruit due to grafting on the local bottle gourd rootstocks in comparison to the non-grafted and grafted CT fruit on commercial rootstocks (Çandır et al 2013). The most abundant sugar was sucrose at harvest and after storage period in both cultivars as reported previously (Chisholm & Picha 1986; Kyriacou & Soteriou 2015). In general, total soluble solid, total and individual sugar contents did not changed significantly during storage. Similarly, soluble solids content, sucrose, glucose, and fructose concentrations of watermelons mostly did not change during storage for 14 days at 0 °C plus 5 days at 23 °C, but all generally were reduced at higher storage temperatures (Chisholm & Picha 1986). In our study, preservation of sugars at lower storage temperature may be attributed to a presumably lower rate of respiration.

Taste scores (1-9) declined to the lowest level for 21 days of storage at 7 °C for both cultivars (Table 1 and 2). In CR cultivar, fruit on RS-841received higher taste scores than those from other rootstocks and control fruit after 21 days of storage (Table 1). In CT cultivar, fruit grafted on Ferro, Argentario

and RS841 received higher taste scores than those on Macis and control fruit after 21 days of storage (Table 2). Lower taste score may be related to becoming of overripe of control fruit and grafted fruit on Macis rootstock. Furthermore, panelists did not detected off-flavors in fruit from grafted plants. Bruton et al (2009) reported similar findings with the fruit from grafted watermelons.

4. Conclusions

Watermelons grafted on Ferro and RS841 rootstocks maintained higher firmness, lycopene content, C* value and taste scores with lower ripening scores, compared to the control for both cultivars. Macis and Argentario may lead an over-ripening, softening and less intense flesh color with lower lycopene content for CR and/or CT fruit during storage. Ferro and RS841 rootstocks provided a 21-day of storage life at 7 °C and 85-90% relative humidity.

Acknowledgments

This research was supported by the Scientific and Technological Research Council of Turkey (TUBITAK 108 O 391). The authors wish to thank the TUBITAK for their financial support.

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