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[1]Department of Horticulture, Mustafa Kemal University, Antakya, Hatay, Turkey
[2]Department of Horticulture, Erciyes University, Melikgazi, Kayseri, Turkey
[3]Alata Horticultural Research Institute, Erdemli, Mersin, Turkey
[4]Agriculture County Directorate, Silifke, Mersin, Turkey

Effects of rootstocks on storage and shelf life of grafted watermelons

Ahmet Erhan Özdemir[1], Elif Çandır[1*], Halit Yetişir[2], Veysel Aras[3], Ömer Arslan[4], Özay Baltaer[1], Durmuş Üstün[1], Mustafa Ünlü[2]

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Summary

Watermelon fruits from non-grafted or grafted 'Crimson Tide' (CT) and 'Crisby' (CR) onto Ferro, RS841, Argentario and Macis rootstocks were compared for their postharvest quality during storage at 7 °C for 21 days and additional 7 days at 21 °C. Non-grafted and grafted CT and CR fruits did not exhibit chilling injury (CI) symptoms, but the 1-2% of fungal decay occurred after shelf life period following storage. Watermelons grafted on Ferro and RS841 rootstocks had higher flesh firmness thicker rind, lower ripening rating, more intense (higher C*) brighter red (lower h° value) color and higher lycopene content after shelf life period following storage, compared to non-grafted fruits. All of the fruit tested by the panelists received high taste scores of >7.9 out of 8.5 at the beginning, but the scores decreased to >6.8 out of 7.7 at the end of shelf life period. Watermelons could successfully be kept for 21 days at 7 °C and additional 7 days at 21 °C. Watermelons grafted on Ferro and RS841 rootstocks had higher postharvest quality, compared to the non-grafted fruits for both cultivars.

Introduction

Turkey is an important vegetable producing country with total of 27 billion metric tons vegetable production (FAOSTAT, 2014). The Cucurbitaceae family comprises 28% of total vegetable production of Turkey. Watermelon accounts for 14% of total vegetable production. Turkey is the second largest watermelon-producing country in the world after China, with production of 4 million tons per year. Recently, grafted watermelon production has become widespread in Turkey, because soil borne diseases are severe during early cultivation under plastic tunnels or later in the season in field production due to continuous and intensive cropping (Kurt et al., 2002).

Soil borne diseases cause a decrease in yield and quality. There are different ways to prevent soil-borne diseases such as crop rotation, breeding programs, soil fumigant (Yetisir and Sari, 2004). However, the use of methyl bromide has been banned due to its effect on depletion of ozone layer. The use of seedlings grafted on *Cucurbita* and *Lagenaria* rootstocks, which have an acquired resistance to soil borne diseases, was suggested by several researchers as an environmentally safe alternative to methyl bromide (Miguel et al., 2004). Owing to environmental restrictions imposed on the use of chlorofluorocarbon-based soil fumigants, use of rootstocks resistant to soil borne pathogens has become an established practice in regions growing watermelon (Davis and Perkins-Veazie, 2005). The most common rootstocks for watermelon are bottle gourd, interspecific hybrids between *C. maxima* and *C. moschata*, and wild watermelon (*Citrullus lanatus* var. citroides) (Davis et al., 2008). Grafting of watermelon scions on squash, pumpkin, or bottle gourd rootstocks is practiced in all the major watermelon production regions of the world (Lee, 1994; 2003). These rootstocks influenced resistance to soil borne diseases, plant growth, yield, and fruit quality. Graft incompatibility and decrease in the fruit quality appeared depending on the scion-rootstock combination (Lee and Oda, 2003).

Although effects of rootstocks on yield have been reported, the information on fruit quality has been incidental and does not account for all correlative aspects of quality. Abnormal fruit quality has been reported due to grafting for watermelon (Yamasaki et al., 1994; Lee and Oda, 2003; Liu et al., 2006; Alexopoulos et al., 2007). However, there are other reports of positive effects of grafting on watermelon fruit quality (Yetisir and Sari, 2003; Davis and Perkins-Veazie, 2005; Karaca et al., 2012; Çandir et al., 2013). The effect of the rootstocks on plant growth, fruit yield and quality of watermelon cv. Crispy grafted onto TZ-148 and RS841 of commercial hybrid of *Cucurbita maxima* × *Cucurbita moschata* and 64-18 of experimental bottle gourd rootstocks were studied. Grafting resulted in higher yield by increasing in both fruit number and weight, however, no detrimental effect on fruit quality such as fruit index, rind thickness, and soluble solid contents on grafted plants was observed (Alan et al., 2007). Grafting on the local bottle gourd rootstocks improved plant growth parameters, yield (Karaca et al., 2012) and the total soluble solid (TSS), titratable acidity (TA), TSS/TA ratio, sugar, organic acid, and carotenoid (β-carotene and lycopene) contents of Crimson Tide fruits (Çandir et al., 2013).

For short-term storage or transit to distant markets (>7 days), most recommendations use 7.2 °C (45 °F) and 85-90% R.H. as the acceptable handling conditions for watermelons (Suslow, 1997). Watermelons are, however, prone to chilling injury at this temperature and extended holding at this temperature will induce chilling injury, rapidly evident after transfer to typical retail display temperatures (Suslow, 1997). Short-term storage at near ambient temperatures is the common practice for watermelon (Chisholm and Picha, 1986; Perkins-Veazie and Collins, 2006; Radulović et al., 2007). Watermelons in most of the world are customarily handled postharvest under non-refrigerated conditions. Shelf life for watermelon is 2-3 weeks at 10-15 °C depending on cultivar (Rushing et al., 2001). There are few reports on the effects of grafting on storage and shelf life of watermelons. Effects of grafting on postharvest quality of watermelon are not completely known and cause some speculation. Previous studies have shown that grafting increased in flesh firmness of watermelon fruits in most scion-rootstock combinations (Salam et al., 2002; Yetisir et al., 2003; Davis and Perkins-Veazie, 2005; Roberts et al., 2007; Cushman and Huan, 2008; Bruton et al., 2009; Soteriou and Kyriacou, 2015). Firmer fruits are more likely to retain a desirable consistency 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 and shelf life performances of watermelon fruits have gained importance.

The objective of this study was to determine quality changes of watermelon fruits cv. 'Crimson Tide' (CT) and 'Crisby' (CR) grafted onto Ferro, RS841, Argentario, and Macis rootstocks during storage at 7 °C for 21 days and additional 7 days at 21 °C and compare graf-

* Corresponding author

ted and non-grafted 'Crimson Tide' and 'Crisby' fruits for postharvest quality.

Materials and methods

The experiment was conducted at the Alata Horticultural Research Institute, Erdemli, Mersin, Turkey. 'Crimson Tide' (CT) and Crisby (CR) watermelon [*Citrullus lanatus* (Thunb.) Matsum. and Nakai] cultivars were grafted onto Ferro and RS841 (*C. maxima* × *C. moschata*) and Argentario and Macis (*Lagenaria siceraria*) rootstocks by using slunt cut grafting method (Lee and Oda, 2003). The grafted plants were supplied by the commercial seedling company of Grow Fide (Antalya, Turkey). The non-grafted CT and CR were used as control.

Fruits were harvested at full maturity when the 75% of tendril and stipule on the same node with peduncle were desiccated. After harvest, fruits were stored at 7±0.5 ºC and 90±5 % relative humidity for 21 days in cold store and hold 21 days at 7 °C and subsequent 7 days at 21±0.5 ºC and 70±5% relative humidity for shelf life. Changes in fruit weight (g), diameter (mm) and length (mm), rind thickness (mm), weight loss (%), fruit flesh firmness (N), taste (1-9), total soluble solids (%), juice pH, titratable acidity (%), chilling injury and fungal decay (1-5), flesh color (L* C* hº) values, hallow heart (1-5), ripening (1-7), citric and malic acid (%), glucose (%), fructose (%), sucrose (%), total sugar (%), β-carotene (μg g^{-1}), lycopene (μg g^{-1}) were determined after shelf life period following storage at a weekly interval.

Fruit weight (g); 30 fruits were weighted by a laboratory balance with an accuracy of 0.01 g for grafted and non-grafted fruits of both cultivars; it was calculated by taking the arithmetic mean. Diameter (mm) and length (mm); 5 fruits in each replicate were measured with a ruler. Rind thickness was measured at two points on each fruit cross-section using an electronic caliper. Weight loss (%); 30 fruits were numbered and they were weighted by a laboratory balance with an accuracy of 0.01 g for grafted and non-grafted fruits of both cultivars, the loss was calculated by subtracting the final weigh from the initial weigh in percent. Fruit flesh firmness (N); Flesh firmness of the middle of each fruit was determined with a penetrometer (Now FHR-5 Nippon Optical Works Co. Ltd. Tokyo, Japan). This involved measuring the force in kilograms required for a 12-mm conical probe to penetrate the cut surface to a depth of 5 mm at 3 locations in the mesocarp tissue; the results were then converted to newton (N). As described by Motsenbocker and Picha (1996), a 2.5-cm cross-sectional slice was taken from the middle of each fruit. The flesh of each slice was carefully removed from the outer rind and quartered. Two opposite quarter pieces were combined and homogenized for one minute in a Waring Blender and filtered under suction through Whatman #4 paper. Portions of the homogenate were used to determine total soluble solid (TSS) content, juice pH, titratable acidity (TA). TSS content was measured using a digital refractometer (Atago Model ATC-1E Atago Co. Ltd., Tokyo, Japan) and juice pH with digital pH-meter (Orion 5-Star model Thermo Fisher Scientific Inc., MA, ABD) at 20 °C. TA was measured by potentiometric method. The 5 ml of juice sample was diluted with distilled water to 100 ml and this sample was titrated with 0.1 N NaOH until the pH value of 8.1 was read on digital pH-meter. The results were calculated as "g malic acid 100 ml^{-1} juice" in percent. The fruits were also scored at each evaluation for chilling injury (CI) and decay (1 = none, 2 = <10% of surface area, 3 = 11% to 25%, 4 = 26% to 50%, and 5 = >50%) (Risse et al., 1990). Incidence of CI and decay were determined after 7 days at 21 °C following each sto-rage period. For sensory evaluation, two opposite quarter pieces from the middle of each fruit were prepared as described above. Ten trained panelists (non-smoker 7 male and 3 female, ages 20 to 45) evaluated taste (1-9) of fruits on hedonic scale of 1=disliked (lowest value) to 9=liked (the best), hallow heart (1-5) of fruits on a scale of 1=none to 5=very severe (50% "more than hallow heart) and ripening (1-7) of fruits on a scale of 1= raw fruit and 3=mature to 7=overripe extremely. Fruit flesh color was measured using the CIELAB (L*a*b*) color space by a CR-300 Minolta Chroma Meter (Konica Minolta, Osaka, Japan), calibrated using the manufacturer's standard white plate. Two readings were performed from the flesh of vertically cut fruits. L* represents lightness, ranging from 0 (black) to 100 (white). Chroma (C*) represents color saturation, which varies from dull (low value) to vivid color (high value) and was calculated using the formula $(a^2 + b^2)^{1/2}$. Hue angle (h°) represents a color wheel with red-purple at an angle of 0°, yellow at 90°, bluish green at 180°, and blue at 270°, and it was calculated by $h° = \tan{-1}$ (b/a) (McGuire, 1992).

Sugars and organic acids were extracted of the method described by Çandır et al. (2013). Briefly, frozen samples were homogenized using an Ultra-Turrax T25 model homogenizer (IKALabortechnik) at low speed with a 10-mm shaft. The resulting slurry was filtered through Whatman No. 4 paper with a Buchner funnel under vacuum. Exactly 1 mL of sample was diluted with deionized distilled water to a total volume of 10 mL. After vortexing for 1 min, 20 μL of sample was injected directly into the HPLC equipment after filtration through a Millex-HV 0.45 μm filter (Millipore). HPLC analysis of sugars and organic acids was performed on LC-10A equipment consisting of LC-10AD pumps, an in-line degasser, a CTO-10A column oven, an SCL-10A system controller, an SPD 10Avp, a photo diode array (PDA) detector, and a refractive index detector (RID), all operated by LC solution software (Shimadzu). Sugars were separated on an EC NUCLEOSIL Carbohydrate 250 mm × 4 mm i.d. column (Macherey-Nagel) at 25 °C. The mobile phase was acetonitrile and water (80:20, v/v) at a flow rate of 2 mL min^{-1}. Organic acids were separated on a TransgenomicTM ICSep ION300 300 mm × 7.8 mm i.d. column (Transgenomic) at 65 °C. The mobile phase was 0.0085 N H_2SO_4 at a flow rate of 0.4 mL min^{-1}. Sugars and organic acids were detected using the RID and PDA detectors at 210 nm, respectively. The quantification was performed according to external standard solution calibrations. The results were expressed as g 100 g^{-1} fresh weight.

Carotenoids were extracted following a modified version of the method described by Perkins-Veazie and Collins (2006). Brefly, frozen samples were homogenized using the Ultra-Turrax homogenizer at low speed with a 10-mm shaft. Three grams of puree were weighed into the centrifuge tube and extracted with HPLC-grade solvents of 10 mL of hexane, 5 mL of ethanol, and 5 mL of acetone containing 0.05% butylated hydroxytoluene (Merck KGaA). Samples were tightly sealed and placed on an orbital shaker (Heidolph Unimax 2010, Heidolph Instruments GmbH Co. KG) for 15 min at 320 rpm, and then 3 mL of deionized distilled water was added and samples were shaken again for 10 min. Afterwards, samples were put in a rack to allow solvent phase separation. The upper hexane layer was also filtered using a Millex-HV 0.45-μm filter (Millipore) and 20 μL of sample was injected directly into Shimadzu HPLC equipment (as previously described). Carotenoids were separated on a YMC carotenoid column, C30 250 mm × 4.6 mm id, 5 μm particle size (YMC Europe GMBH), operating at 30 °C with a flow rate of 1.5 mL min^{-1}. The mobile phase was solvent A (methanol, methyl tertiary butyl ether, and deionized distilled water, 81:15:41) and solvent B (methanol and methyl tertiary butyl ether, 10:90) with elution with a linear gradient of 0-16 min with 100% A and 16-60 min with 100% B (Liu et al., 2009). Detection was carried out at 503 nm for lycopene and 452 nm for β-carotene using the PDA detector. Components were identified by comparison of their retention times to those of authentic standards under analysis conditions and were quantified by external standard method and expressed as μg g^{-1} fresh weight.

The study was performed over a 2-year period, in 2009 and 2010. Data are represented as the mean of 2 experimental years. In the watermelon production region where the experiment was conducted,

farmers start the season with early season cultivar 'Crisby' followed by mid-early/middle season cultivar 'Crimson Tide'. Crisby has a mealy texture while Crimson Tide is crisp. Our objective in this experiment was to determine the commercial rootstock(s) with best storage and shelf life performance for each cultivar, not to determine the best scion/rootstock combination(s) for watermelon producing area. Therefore, the experiment was conducted in completely randomized block design and the data were analyzed by one-way ANOVA using SAS software of SAS Institute, Cary, N.C. (SAS, 1999). The data were obtained from three replicates per scion/rootstock combination. Each replicates contained 5 fruits. Mean separation was performed by Fisher's Least Significance Test at p<0.05 level.

Results and discussion

Watermelons grafted on RS841 and Ferro rootstocks had the higher fruit weight for CT and CR cultivars (Tab. 1). An increase in fruit weight due to grafting was reported in previous studies (Yetisir et al., 2003; Miguel et al., 2004; Alexopoulos et al., 2007; Alan et al., 2007; Prioetti et al., 2008). Grafting had no significant effect on fruit length and diameter for both cultivars (Tab. 1). Similarly, Davis et al. (2008) reported that fruit shape, determined by length, circumference, and their ratio, did not change significantly from watermelon fruit harvested from grafted and not grafted plants. Grafting affected rind thickness dependent on the scion. Consistent with these findings, Soteriou and Kyriacou (2015) reported that variability in rind thickness was derived mainly from the scion. At harvest, CT fruits from grafted plants had thicker rind than those from non-grafted plants while grafting did not affect rind thickness for CR watermelon cultivar (Fig. 1). Rind thickness of 'Crisby' watermelon fruits grafted on TZ-148, RS-841 and 64-18 of *Lagenaria* rootstock was similar to non-grafted control fruits (Alan et al., 2007). Interspecific hybrid rootstocks (*C. maxima* × *C. moschata*) increased rind thickness of four watermelon cultivars ('Celebration', 'Gallery', 'Pegasus' and 'Torpilla') although their effect was very limited, indicating minimal rootstock effect on rind thickness compared with the effect of cultivar (Kyriacou and Soteriou, 2015). Alexopoulos et al. (2007) reported that 'Crimson Sweet' fruits from grafted plants on rootstocks (Long gourd, Early Max, Max-2 and F-14 gourd), had a thicker rind than the fruits from non-grafted plants. Davis et al. (2008) also found rind thickness increased for both seedless and seeded watermelon fruits when grafted to gourd rootstock '451'. In the study with 'Crimson Tide' watermelon fruits, all of the grafted plants on bottle gourd rootstocks produced fruit with a thicker rind than the control plants (Karaca et al., 2012). Rind thickness decreased in non-grafted and at a lesser extent in grafted fruits during storage at 7 °C for 21 days and additional 7 days at 21 °C in both cultivars (Fig. 1). Fruits grafted on RS841, Argentario and Ferro rootstocks had thicker rind compared to non-grafted fruits after shelf life period following storage for both cultivars (Fig. 1). Similarly Kyriacou and Soteriou (2015) reported that postharvest storage at 25 °C caused thinning of the rind after 7 and 14 days and all hybrid rootstocks resulted in thicker rind than the non-grafted control. Thinning of the rind, known to characterize watermelon maturation (Corey and Schlimme, 1988), therefore may indicate an overripe fruit and one subjected to prolonged storage (Kyriacou and Soteriou, 2015).

Weight losses of grafted and non-grafted fruits were very low (<1 %) after shelf life period for 7 days at 21° following 21 days of storage at 7 °C for both cultivars. Effect of rootstocks on weight loss was not significant (Fig. 2). Consistent with our results, Perkins-Veazie and Collins (2006) reported the <1 % of weight loss in watermelon fruits 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.

Non-grafted CT and CR or CT and CR grafted onto different rootstocks did not exhibit CI symptoms, but the 1-2 % of fungal decay occurred during shelf life period after 21 days of storage (Fig. 3). The decayed areas covered <10 % of rind surface of fruits for both cultivars. The graft combinations did not differ in the incidence of fungal decay for CR cultivar. With CT cultivar, fruits grafted on Ferro

Tab. 1: Effects of rootstocks on fruits weight, diameter and length of 'Crimson Tide' (CT) and 'Crisby' (CR) watermelon fruits at harvest

Scion / rootstock	Fruit weight (g)	Fruit diameter (mm)	Fruit length (mm)
CR			
Control	4814.29c	21.07a	21.00a
Macis	5653.78ab	21.55a	21.80a
Argentario	5251.60bc	21.50a	21.92a
RS841	6076.50a	22.01a	22.14a
Ferro	6058.54a	22.17a	22.95a
CT			
Control	6316.41c	21.26a	24.66a
Macis	6343.75c	22.26a	25.81a
Argentario	6668.41b	22.92a	26.37a
RS841	6914.47a	21.60a	25.33a
Ferro	6814.06ab	21.99a	25.60a

[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.

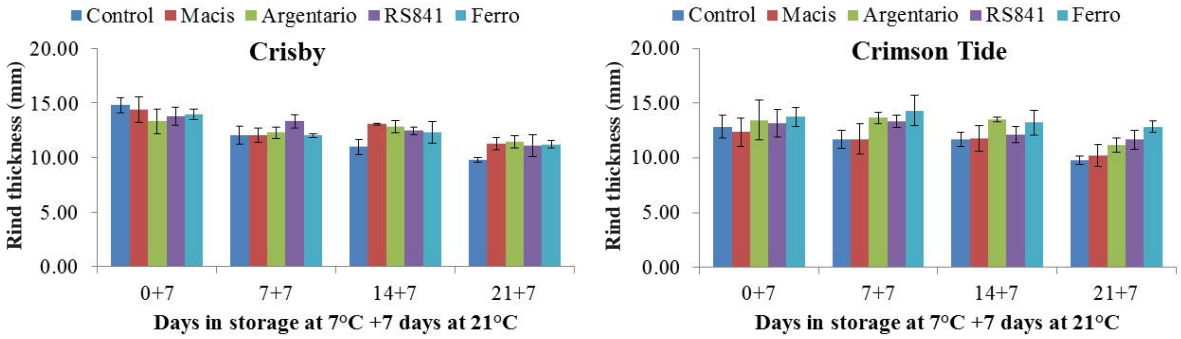

Fig. 1: Effects of rootstocks on rind thickness of 'Crisby' and 'Crimson Tide' watermelon fruits after shelf life period for 7 days at 21 °C following storage at 7 °C

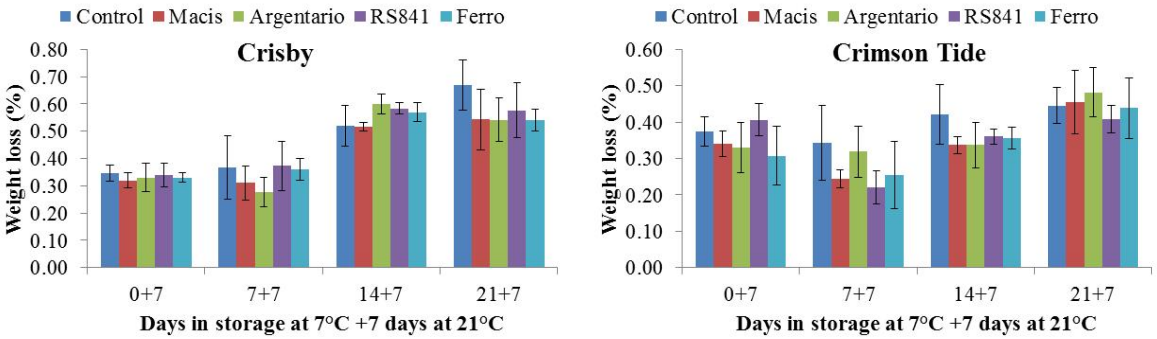

Fig. 2: Effects of rootstocks on weight loss of 'Crisby' and 'Crimson Tide' watermelon fruits after shelf life period for 7 days at 21 °C following storage at 7 °C

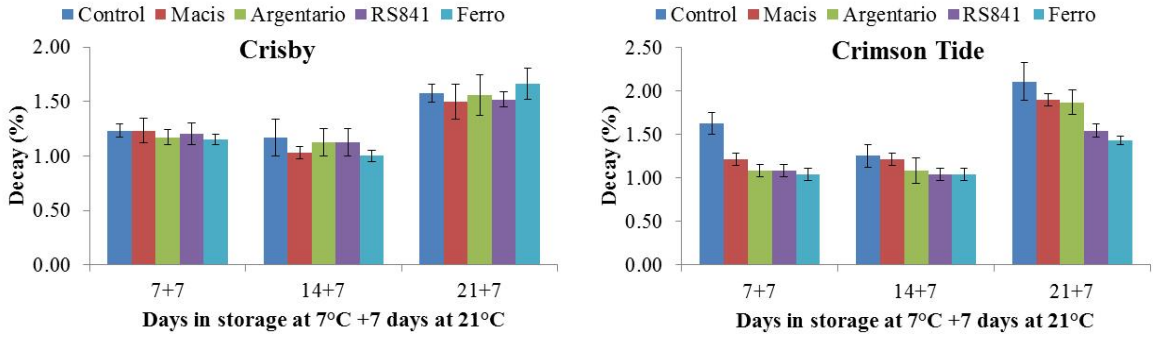

Fig. 3: Effects of rootstocks on fungal decay of 'Crisby' and 'Crimson Tide' watermelon fruits after shelf life period for 7 days at 21 °C following storage at 7 °C

(1.43%) and RS841 (1.54%) rootstocks had the lower fungal decay than those on Argentario (1.87%), Macis (1.90%) and control fruits (2.11%) after shelf life period for 7 days at 21° following 21 days of storage at 7 °C. In this study, increased in storage time and subsequent shelf life period resulted in the surface decay caused by different fungi. *Botrytis cinerae, Alternaria cucumerina, Cladosporium cucumerinum, Fusaium* spp., *Penicillium digitatum* and *P. italicum*, the most encountered fungi identified followed by *Colletotrichum orbiculare* and *Stemphylium* spp. Grafted and non-grafted watermelon fruits did not show differential susceptibility to the those pathogen. Out of pathogen identified, *B. cinerae, C. cucumerinum Stemphylium* spp. were first time described as additional pathogens to other previously known species causing postharvest decay of watermelon. Postharvest rots caused by Fusarium spp. and *Phytophthora capsici* are of concern because control measures for these fungi in the field often are inadequate. With good disease control in the field, anthracnose (*C. orbiculare*) and black rot (*Didymella bryoniae*) rarely develop on watermelon (Rushing et al., 2001).

Flesh firmness decreased during storage at 7 °C for 21 days and additional 7 days at 21 °C for both cultivars and grafted fruits had firmer comparing to non-grafted fruits (Tab. 2). Our data suggest that effects of rootstocks on flesh firmness varied depending on the rootstock and the scion. Watermelons grafted on Ferro and RS841 rootstocks had the higher fruit flesh firmness for CT and CR cultivars. Non-grafted fruits had the lowest fruit flesh firmness after shelf life period following storage for CR and CT cultivars. At harvest, an increase in flesh firmness due to grafting has been reported. (Salam et al., 2002; Yetisir et al., 2003; Davis and Perkins-Veazie, 2005; Roberts et al., 2007; Cushman and Huan, 2008; Bruton et al., 2009; Soteriou and Kyriacou, 2015) while grafting on some rootstocks seems not affect watermelon firmness (Karaca et al., 2012). The findings of Kyriacou and Soteriou (2015) indicated that *C. maxima* × *C. moschata* hybrids sustained higher postharvest flesh firmness compared with non-grafted controls, while rootstock effect was superior to that of cultivar and storage. Watermelon fruit flesh firmness did not change or reduced during storage during 4 weeks of storage at 5°, 10°, 15° or 20 °C depending on storage temperature and cultivars (Risse et al., 1990). Depending on cultivar, seasonal variation and harvest maturity, postharvest decline in flesh firmness may compromise fruit quality within 14 days from harvest (Kyriacou and Soteriou, 2015).

Juice pH value slightly decreased during storage at 7 °C for 21 days and additional 7 days at 21 °C. Similarly, lower pH values were reported in 'Charleston Gray' watermelons fruits after storage at 7 °C for 14-19 days (Chisholm and Picha, 1986) and 'Fantasy F1' watermelons after storage at 20 °C for 14 days (Radulović et al., 2007) compared to the pH values at harvest. In CR cultivar, non-grafted fruits had higher pH comparing to grafted fruits. In CT cultivar, fruits on RS841 rootstock resulted in lower pH than those on other rootstocks and non-grafted fruits after shelf life period following storage (Tab. 3). Grafting of mini-watermelons on commercial hybrid rootstock PS 1313 had no effect on juice pH (Proietti et al., 2008) while grafted 'Crimson Tide' watermelons on some local bottle gourd rootstocks had lower juice pH, compared to control (Çandir et al., 2013).

TA content slightly increased in parallel with changes in juice pH during storage at 7 °C for 21 days and additional 7 days at 21 °C for both cultivars (Tab. 3). In CR cultivar, fruits on RS841 and Ferro rootstocks had higher TA than those on other rootstocks and non-grafted fruits after 7 days at 21 °C following 21 days storage at 7 °C. In CT cultivar, fruits on RS841 rootstock resulted in higher TA than those on other rootstocks and non-grafted fruits after shelf life period following storage (Tab. 3). Higher TA due to grafting was reported in watermelon fruits (Proietti et al., 2008; Çandir et al., 2013). The malic acid content varied from 0.23% to 0.28% for CR cultivar and 0.23% to 0.31% for CT cultivar and the citric acid content varied

Tab. 2: Effects of rootstocks on some quality attributes of 'Crisby' (CR) and 'Crimson Tide' (CT) watermelon fruits after shelf life period for 7 days at 21 °C following storage at 7°C

Scion / rootstock	Days in storage at 7 °C +7 days at 21 °C				Mean
	0+7	7+7	14+7	21+7	(Rootstock)
Firmness (N)					
CR	6.16c	5.47c	5.25c	3.99c	5.22e
Control	6.31bc	6.24b	5.62c	5.13b	5.83d
Macis	6.86b	6.44b	6.33b	5.54b	6.29c
Argentario	7.65a	7.63a	7.40a	7.09a	7.44a
RS841	7.47a	6.90b	7.31a	5.83a	6.88b
Ferro	6.16c	5.47c	5.25c	3.99c	5.22e
CT					
Control	5.74b	5.60c	4.38e	4.81c	5.13e
Macis	6.06b	6.46bc	5.16d	4.79c	5.62d
Argentario	7.03a	6.49bc	6.05c	5.72b	6.32c
RS841	7.16a	6.88b	6.72b	6.75a	6.88b
Ferro	7.35a	8.29a	7.40a	7.24a	7.57a
Ripening (1-7)					
CR	4.0a	3.4a	3.6a	3.7ab	3.7ab
Control	3.8a	3.6a	3.8a	3.7ab	3.7ab
Macis	3.8a	3.7a	3.9a	4.0a	3.9a
Argentario	3.4a	3.5a	3.5a	3.6b	3.5bc
RS841	3.5a	3.1a	3.6a	3.5b	3.4c
Ferro	4.0a	3.4a	3.6a	3.7ab	3.7ab
CT					
Control	4.6a	5.2a	5.0a	5.2a	5.0a
Macis	4.4a	4.2b	4.4b	5.1a	4.5b
Argentario	3.3b	4.0b	3.9bc	4.7b	4.0cd
RS841	3.7b	4.1b	4.3b	4.6b	4.2c
Ferro	3.2b	3.5b	3.7c	4.5b	3.7d
TSS(%)					
CR					
Control	10.6c	10.1c	10.4b	10.3c	10.4d
Macis	10.2bc	10.3c	10.6b	10.1c	10.3d
Argentario	10.8b	10.6b	10.6b	10.5bc	10.6c
RS841	10.9ab	10.8ab	11.0a	10.8ab	10.9b
Ferro	11.4a	11.0a	11.1a	11.0a	11.1a
CT					
Control	10.9a	11.0a	10.8a	11.1a	10.9a
Macis	10.6a	10.4a	10.5a	10.7a	10.5b
Argentario	10.1a	10.6a	10.7a	10.7a	10.5b
RS841	10.9a	10.9a	10.8a	11.2a	11.0a
Ferro	10.3a	10.7a	10.8a	11.1a	10.7ab
Taste (1-9)					
CR	8.1a	6.9a	6.2b	5.3a	6.6c
Control	8.0a	7.0a	6.3b	5.7a	6.8bc
Macis	8.1a	7.3a	6.5ab	5.9a	7.0ab
Argentario	8.2a	7.5a	6.9a	6.1a	7.2a
RS841	8.4a	7.2a	6.9a	5.9a	7.1a
Ferro	8.1a	6.9a	6.2b	5.3a	6.6c
CT					
Control	7.6b	7.3a	6.7c	5.8c	6.8b
Macis	7.9b	7.3a	7.1bc	5.4bc	6.9b
Argentario	8.3a	7.9a	7.6b	6.3b	7.5a
RS841	8.2a	7.8a	7.2bc	6.7bc	7.5a
Ferro	8.2a	7.6a	8.3a	6.5a	7.7a

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 $P<0.05$.

Tab. 3: Effects of rootstocks on juice pH, TA and organic acid content of 'Crisby' (CR) and 'Crimson Tide' (CT) watermelon fruits after shelf life period for 7 days at 21 °C following storage at 7 °C

Scion / rootstock	Days in storage at 7 °C +7 days at 21 °C				Mean
	0+7	7+7	14+7	21+7	(Rootstock)
Juice pH					
CR					
Control	5.80a	5.60a	5.55a	5.70a	5.66a
Macis	5.67b	5.48a	5.60a	5.61b	5.59bc
Argentario	5.68b	5.57a	5.56a	5.61b	5.60bc
RS841	5.59c	5.52a	5.62a	5.48c	5.55c
Ferro	5.63bc	5.53a	5.56a	5.44c	5.54c
CT					
Control	5.69a	5.57a	5.62a	5.59a	5.62a
Macis	5.60a	5.57a	5.60ab	5.60a	5.59a
Argentario	5.62a	5.44b	5.53c	5.48a	5.52b
RS841	5.59a	5.45b	5.55bc	5,39b	5.50b
Ferro	5.61a	5.47b	5.44d	5.50a	5.50b
TA (%)					
CR					
Control	0.16b	0.18a	0.17a	0.17b	0.17bc
Macis	0.16b	0.17a	0.15a	0.17b	0.16c
Argentario	0.16b	0.17a	0.16a	0.16b	0.16c
RS841	0.18a	0.19a	0.16a	0.19a	0.18a
Ferro	0.17ab	0.18a	0.17a	0.19a	0.18ab
CT					
Control	0.17a	0.18b	0.17b	0.18b	0.18b
Macis	0.17a	0.16c	0.15c	0.16c	0.16c
Argentario	0.16a	0.18b	0.17b	0.17bc	0.17bc
RS841	0.17a	0.20a	0.19a	0.20a	0.17a
Ferro	0.17a	0.19a	0.17b	0.17bc	0.18b
Citric acid (%)					
CR					
Control	0.07a	0.08a	0.04ab	0.06a	0.06a
Macis	0.07a	0.06a	0.03b	0.06a	0.06a
Argentario	0.08a	0.07a	0.05a	0.07a	0.07a
RS841	0.08a	0.09a	0.05a	0.07a	0.07a
Ferro	0.09a	0.07a	0.05a	0.07a	0.07a
CT					
Control	0.10a	0.12a	0.10a	0.06bc	0.09a
Macis	0.09a	0.07b	0.05b	0.04c	0.06c
Argentario	0.09a	0.11ab	0.04b	0.04c	0.07b
RS841	0.10a	0.12a	0.06b	0.08a	0.09a
Ferro	0.07a	0.14a	0.08a	0.07ab	0.09a
Malic acid (%)					
CR					
Control	0.22b	0.25bc	0.23bc	0.26bc	0.24b
Macis	0.22b	0.24c	0.22c	0.28c	0.24b
Argentario	0.21b	0.23c	0.23bc	0.24c	0.23b
RS841	0.25a	0.29a	0.27a	0.33a	0.28a
Ferro	0.25a	0.27ab	0.26ab	0.35ab	0.28a
CT					
Control	0.24a	0.27c	0.25bc	0.24b	0.25bc
Macis	0.23a	0.25c	0.23c	0.21c	0.23c
Argentario	0.25a	0.38ab	0.25bc	0.23bc	0.28ab
RS841	0.24a	0.43a	0.28ab	0.29a	0.31a
Ferro	0.19a	0.36b	0.31a	0.28a	0.29b

[aX] 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.

from 0.06% to 0.07% for CR cultivar and 0.06% to 0.09% for CT cultivar after shelf life period following storage (Tab. 3). The citric acid content was not affected by grafting for CR. In CT, fruits grafted on RS841 and Ferro had higher citric acid content after shelf life period for 7 days at 21° following 21 days of storage at 7 °C, compared to other graft combination and control. Malic acid was the predominant organic acid for both cultivars. Compared to the control and fruits from other graft combination, watermelons grafted on RS841 rootstock had higher malic acid content for CR and CT cultivars during storage at 7 °C for 21 days and additional 7 days at 21 °C.

We found a slight increase in ripening ratings during storage at 7 °C for 21 days and additional 7 days at 21 °C for both cultivars (Tab. 2), indicating fruits became overripe toward the end of 21 days of storage and subsequent shelf life period. 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. Fruits grafted on RS841 and Ferro rootstocks for CR cultivar and fruits grafted on RS841, Argentario and Ferro rootstocks for CT cultivar had the lowest ripening ratings after shelf life period following storage (Tab. 2). Ripening could be retarded by grafting in watermelon fruits at harvest. Roberts et al. (2007) suggested that grafting may delay the harvest date by about 7 days. 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.

TSS content remained above 10% throughout during storage at 7 °C for 21 days and additional 7 days at 21 °C for both cultivars (Tab. 2), rendering fruit acceptable for perceived sweetness as reported by (Kyriacou and Soteriou (2015). In, CR cultivar, fruits grafted on Ferro rootstock had higher TSS content after shelf life period for 7 days at 21° following 21 days of storage at 7 °C, compared to other graft combination and control (Tab. 2). In case of CT cultivar, control and grafted fruits had similar TSS content after shelf life period following storage (Tab. 2). Although some previous studies (Miguel et al., 2004; Proietti et al., 2008; Bruton et al., 2009; Balazs et al., 2011; Bekhradi et al., 2011; Soteriou and Kyriacou, 2015) showed that grafting had no effect on TSS, grafting on the bottle gourd rootstocks increased TSS contents of watermelon fruits compared to the control (Salam et al., 2002; Karaca et al., 2012; Çandir et al., 2013). Unlike our findings, in other studies, grafted watermelon fruits had lower TSS content compared to non-grafted controls (Davis and Perkins-Veazie, 2005; Roberts et al., 2007; Kyriacou and Soteriou, 2015). Yetisir et al. (2003) reported that quality (brix, firmness, rind thickness, and fruit shape) of watermelon was greatly affected by grafting, but the results were dependent on the rootstock used. The differences in reported results may be due in part to different production environments, type of rootstock, interactions between specific rootstocks and scions, and harvest date (Davis et al., 2008).

The most abundant sugar was sucrose at harvest and during storage at 7 °C for 21 days and additional 7 days at 21 °C in both cultivars as reported previously (Chisholm and Picha, 1986; Kyriacou and Soteriou, 2015). In general, changes in on total soluble solid, total and individual sugar contents were not significant during storage and shelf life. In contrast to our findings, in previous studies, it was reported an accumulation of sucrose accompanied the decline in total soluble carbohydrates and soluble solids content in grafted and non-grafted watermelons during storage for 14 days at 25 °C (Kyriacou and Soteriou, 2015) and a significant decrease soluble solids and total sugar contents of watermelons during storage for 14 days at 20 °C (Radulović et al., 2007). In another study showed that soluble solid 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 and Picha, 1986). Similarly, total soluble solid content of watermelon cultivars decreased with increased storage temperature (Risse et al., 1990; Perkins-Veazie and Collins, 2006). In our study, preservation of sugars at lower storage temperature may be attributed to a presumably lower rate of respiration. In CR cultivar, effect of grafting on total and individual sugar contents was not significant after shelf life period following storage (Tab. 4). In CT cultivar, although sucrose and total sugar contents were not affected by grafting, fructose and glucose content were higher in fruits grafted on RS841, Ferro and Argentario rootstocks than those on Macis and non-grafted fruits after shelf life period for 7 days at 21° following 7 days of storage at 7 °C (Tab. 4). The differences in fructose and glucose contents between grafted and non-grafted fruits disappeared afterwards. In some studies, grafted watermelon fruits had lower (Yetisir et al., 2003; Davis and Perkins-Veazie, 2005; Roberts et al., 2007) or similar (Miguel et al., 2004; Proietti et al., 2008; Bruton et al., 2009; Bekhradi et al., 2011) sugar content compared to non-grafted controls. Similarly, Kyriacou and Soteriou (2015) reported that between the hybrid rootstocks, mean sucrose concentration was undifferentiated. In some studies, grafting on the local bottle gourd rootstocks increased fructose, glucose, and sucrose contents of 'Crimson Tide' watermelon fruits compared to the control and commercial rootstock grafts (Çandir et al., 2013). On the other hand, the fruits of the non-grafted Bonta watermelon plants had higher sucrose content than the fruits from the grafted plants on the interspecific hybrid rootstock RS 841 and the *Lagenaria* rootstock FR Strong, while the reducing sugar content (glucose and fructose) showed an opposite pattern (Balazs et al. 2011).

Taste scores (1-9) declined to the lowest level after shelf life period for 7 days at 21° following 21 days of storage at 7 °C (Tab. 2). The effect of rootstock on the taste of watermelon fruits was found to be significant. As the storage time extended, taste tented to decrease, all of the fruit tested by the panelists received high taste scores of >7.9 out of 8.5 at the beginning and decreased to scores of >6.8 out of 7.7 at the end of shelf life, with the exception of non-grafted fruits and fruits grafted on Macis rootstock, which had lower taste scores than the other rootstocks after shelf life period following storage for CR and CT cultivars. Lower taste score may be related to becoming of overripe of control fruits and grafted fruits on Macis rootstock. Furthermore, no off-flavors were detected in fruit from grafted plants. The similar results were obtained in another study conducted on the fruit from grafted watermelons (Bruton et al., 2009).

Flesh color lightness (L* value) decreased during storage at 7 °C for 21 days and additional 7 days at 21 °C for both cultivars (Tab. 5). Similarly Perkins-Veazie and Collins (2006) indicated darker (lower L* values) fruits after storage at 21 °C than in freshly harvested watermelons. Grafting did not affect flesh color lightness during storage, but RS841and Ferro rootstocks resulted in darker fruits after shelf life period for 7 days at 21° following 21 days of storage at 7 °C for both cultivars. Kyriacou and Soteriou (2015) reported that flesh color lightness (L*) of watermelon fruits was affected by rootstock and storage and compared to the non-grafted control, all hybrid rootstocks invariably maintained darker flesh color (lower lightness value) during storage.

The overall intensity of flesh color (C* value), hue angle (h° value) and lycopene content were affected by storage time and rootstocks (Tab. 5). Watermelon flesh color changes from bright red (lower h°) to orange red (higher h°) as ripening level progresses (Karaca et al., 2012). Grafted and non-grafted fruits showed a progressive increase in h° value after shelf life period following storage, indicating a shift from red to orange-yellow. This changes in h° value, characteristic of over-ripening and senescence has been reported after prolonged post-harvest storage of watermelons (Kyriacou and Soteriou, 2015). In both cultivars, C* value continuously decreased during shelf life period at 21 °C following storage at 7 °C. Lycopene content peaked after shelf life period for 7 days at 21° following 7 days of storage at 7 °C for CT cultivars, but it tented to decrease for CR cultivars. Fruits

Tab. 4: Effects of rootstocks on sugar contents of 'Crisby' (CR) and 'Crimson Tide' (CT) watermelon fruits after shelf life period for 7 days at 21 °C following storage at 7 °C

Scion / rootstock	Days in storage at 7 °C +7 days at 21 °C				Mean
	0+7	7+7	14+7	21+7	(Rootstock)
Fructose (%)					
CR					
Control	3.21a	3.10a	3.24a	3.46a	3.25a
Macis	3.22a	3.35a	3.08a	3.89a	3.39a
Argentario	2.94ab	3.43a	3.34a	3.43a	3.29a
RS841	3.15a	3.31a	3.21a	4.23a	3.48a
Ferro	2.73b	3.57a	3.48a	3.90a	3.42a
CT					
Control	2.81ab	2.76b	2.67a	2.80a	2.76b
Macis	2.63b	2.83b	2.78a	2.70a	2.74b
Argentario	3.14a	3.42a	3.24a	3.00a	3.29a
RS841	3.01a	3.79a	3.22a	3.01a	3.16a
Ferro	3.11a	3.74a	3.10a	3.34a	3.32a
Glucose (%)					
CR					
Control	1.66a	1.64a	1.75a	1.75a	1.70a
Macis	1.66a	1.51a	1.63a	1.91a	1.68a
Argentario	1.55a	1.88a	1.81a	1.81a	1.76a
RS841	1.54a	1.63a	1.67a	2.22a	1.76a
Ferro	1.32a	1.87a	1.85a	2.06a	1.77a
CT					
Control	1.79a	1.56c	1.62a	1.55a	1.63b
Macis	1.75a	1.63bc	1.68a	1.55a	1.65b
Argentario	1.73a	1.81bc	1.64a	1.61a	1.70b
RS841	1.86a	1.86b	1.88a	1.78a	1.85a
Ferro	1.81a	2.16a	1.66a	1.80a	1.86a
Sucrose (%)					
CR					
Control	4.47a	3.72a	3.89a	4.69a	4.19a
Macis	4.85a	4.31a	4.16a	4.65a	4.49a
Argentario	5.27a	4.33a	3.94a	5.26a	4.70a
RS841	4.72a	4.41a	4.54a	3.57a	4.31a
Ferro	4.94a	4.06a	4.66a	4.12a	4.45a
CT					
Control	4.90a	5.39a	5.65a	4.81a	5.19a
Macis	4.47a	4.89a	4.77a	4.56a	4.67a
Argentario	4.35a	6.21a	4.76a	4.82a	5.04a
RS841	4.86a	5.23a	4.39a	3.94a	4.61a
Ferro	4.27a	5.44a	4.51a	4.66a	4.72a
Total sugar (%)					
CR					
Control	9.34a	8.45a	8.87a	9.89a	9.14a
Macis	9.73a	9.17a	8.87a	10.45a	9.55a
Argentario	9.76a	9.64a	9.08a	10.49a	9.74a
RS841	9.40a	9.35a	9.42a	10.01a	9.54a
Ferro	8.97a	9.49a	9.99a	10.07a	9.63a
CT					
Control	9.50a	9.71b	9.93a	9.15a	9.57a
Macis	8.84a	9.34b	9.23a	8.81a	9.05a
Argentario	9.22a	11.85a	9.63a	9.42a	10.03a
RS841	9.73a	10.45ab	9.49a	8.72a	9.60a
Ferro	9.18a	11.34a	9.27a	9.79a	9.90a

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 $P<0.05$.

Tab. 5: Effects of rootstocks on color and total lycopene content of 'Crisby' (CR) and 'Crimson Tide' (CT) watermelon fruits after shelf life period for 7 days at 21 °C following storage at 7 °C

Scion / rootstock	Days in storage at 7 °C +7 days at 21 °C				Mean
	0+7	7+7	14+7	21+7	(Rootstock)
L*					
CR					
Control	44.02a	45.50a	44.24a	44.04a	44.45ab
Macis	46.61a	46.77a	46.91a	42.29ab	45.65a
Argentario	44.84a	44.91a	43.48a	44.02a	44.31b
RS841	44.99a	45.40a	43.29a	41.10b	43.70b
Ferro	43.08a	44.74a	43.60a	41.48b	43.23b
CT					
Control	44.87a	44.28a	43.70a	45.55a	44.60a
Macis	46.42a	43.96a	41.51a	44.36ab	44.06a
Argentario	44.87a	44.80a	44.72a	40.22c	43.65ab
RS841	43.74a	43.02a	42.29a	41.52bc	42.64b
Ferro	44.76a	43.25a	41.73a	40.83c	42.64b
C*					
CR					
Control	32.75b	30.91b	26.95b	27.81b	29.61c
Macis	33.32b	30.86b	30.72a	31.40a	31.57b
Argentario	32.58b	34.26a	31.58a	31.29a	32.43ab
RS841	35.76a	33.99a	31.74a	32.40a	33.47a
Ferro	35.86a	34.39a	31.37a	31.94a	33.39a
CT					
Control	35.27c	32.28a	15.49c	28.37c	27.85a
Macis	37.01bc	33.98a	16.15bc	30.16b	29.33a
Argentario	39.74a	36.33a	16.41bc	31.38ab	30.97a
RS841	39.10ab	34.09a	16.94b	32.67a	30.70a
Ferro	37.96ab	35.27a	19.38a	31.68ab	31.07a
h°					
CR					
Control	44.58a	47.14a	47.54b	48.21a	46.87ab
Macis	44.27a	46.69ab	49.85a	47.62a	47.11a
Argentario	44.08a	46.68ab	46.25bc	47.36b	46.09b
RS841	42.72b	44.12c	45.91c	45.04b	44.45c
Ferro	42.41b	45.44b	45.31c	44.34b	44.37c
CT					
Control	45.83a	46.33a	46.40a	45.62a	46.05a
Macis	44.38ab	44.09b	43.69b	47.56a	44.93ab
Argentario	42.72bc	43.72bc	42.95b	46.92a	44.08bc
RS841	42.41bc	42.14b	43.15b	42.27b	42.50d
Ferro	42.34c	42.58c	42.30b	45.71a	43.23cd
Lycopene (µg g^{-1})					
CR					
Control	32.06c	30.12b	25.03c	20.36c	26.89c
Macis	34.65bc	30.53b	22.34d	24.04d	27.89c
Argentario	40.47ab	31.80b	25.94a	26.06a	31.07b
RS841	44.65a	38.04a	29.32b	33.18b	36.30a
Ferro	43.19a	36.36a	32.62a	29.75a	35.48a
CT					
Control	35.42a	39.95c	27.60d	26.81c	32.44b
Macis	36.91a	40.42bc	34.36c	27.61c	34.82b
Argentario	42.99a	43.83abc	40.23ab	33.55b	40.15a
RS841	39.05a	44.55ab	35.78bc	40.09a	39.87a
Ferro	42.41a	47.35a	42.18a	36.86ab	42.20a

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.

grafted on RS841, Argentario and Ferro rootstocks had more intense (higher C*) brighter red (lower h° value) color and higher lycopene content after shelf life period following storage for both cultivars, compared to non-grafted fruits (Tab. 5). In agreement with our results KYRIACOU and SOTERIOU (2015) reported that h° value increased at 14 days of storage indicating yellowing of the flesh and non-grafted control watermelon fruits presented a greater postharvest transition to yellow than the hybrid rootstocks during storage at 25 °C. Postharvest color changes and lycopene biosynthesis in watermelons can be affected by storage temperature and cultivar. PERKINS-VEAZIE and COLLINS (2006) reported that watermelons stored at 21 °C had increased C* value and lycopene content compared to fresh fruit 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. The C* value of grafted and non-grafted watermelon fruits peaked after 7 days at 25 °C was not affected by rootstock. However, the intensity of red color in particular, expressed by component a*, was higher in fruits on rootstocks "TZ148" and "N101" than control fruits (KYRIACOU and SOTERIOU, 2015). Consistent with our results, previous studies have typically shown higher lycopene content in watermelon fruit from grafted plants at harvest (DAVIS and PERKINS-VEAZIE, 2005; DAVIS et al., 2008; PROIETTI et al., 2008; ÇANDIR et al., 2013) and during storage (KYRIACOU and SOTERIOU, 2015). In the current study, changes in lycopene content supports changes in grafted and non-grafted CR and CT watermelon fruits flesh color after shelf life period following storage. The increase in lycopene content, the dominant pigment in watermelon, most likely contributed to the increased C* value as reported by (PERKINS-VEAZIE and COLLINS, 2006). Degradation in lycopene during senescence of non-grafted watermelon fruits of both cultivar and grafted CR fruits after prolonged storage and consequent shelf life period led to decrease in C* and h° value. Although grafted and non-grafted watermelons held for 14 days at 25 °C developed a yellowing of flesh (KYRIACOU and SOTERIOU, 2015), we did not observed any yellowing of flesh in grafted or non-grafted fruit held for 7 days at 21° following 21 days of storage at 7 °C. Flesh color changes was observed in non-grafted fruit, suggesting that fruit ripening occurs faster in non-grafted than in grafted fruit during shelf life period after storage. Ripening ratings also confirmed these changes in non-grafted fruits which became overripe toward the end of storage and shelf life.

β-carotene content did not significantly changed and was not affected by grafting during storage at 7 °C for 21 days and additional 7 days at 21 °C (data not presented). PERKINS-VEAZIE and COLLINS (2006) reported that watermelons stored for 14 days at 21 °C gained 50-139 % in β-carotene compared to fresh fruit, whereas fruit held at 5 and 13 °C changed little in β-carotene content. 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 fruits grafted on some local bottle gourd rootstocks and non-grafted fruits (ÇANDIR et al., 2013).

Effects of grafting on hallow heart was not significant during storage at 7 °C for 21 days and additional 7 days at 21 °C for both cultivars (data not presented). CUSHMAN and HUAN (2008) reported a higher rate of hollow heart incidence in non-grafted watermelon plants than in those that had been grafted. This indicates that hollow heart is affected not only by rootstocks but also by other environmental and cultural conditions.

Many conflicting results have been reported on the changes in fruit quality resulting from grafting (SALAM et al., 2002; LEE and ODA, 2003; DAVIS and PERKINS-VEAZIE, 2005). BRUTON et al. (2009) observed a field and year effect due to soil and climatic conditions on watermelon quality parameters besides rootstock effect. The differences observed in previous studies may be explained by different production conditions, the type of rootstock/scion combinations used, or the harvest date. Since flowering and harvest time are influenced by grafting, the duration of fruit harvest is prolonged, and the number of fruits per plant is increased in grafted plants (YETISIR and SARI, 2003), it is often difficult to harvest fully ripe fruit from grafted plants in large-scale watermelon production where all fruits are harvested in a single harvest.

Watermelons could successfully be kept for 21 days at 7 °C and additional 7 days at 21 °C. Watermelons grafted on Ferro and RS841 rootstocks had higher postharvest quality compared to the control for both cultivars.

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Address of the authors:
Assoc. Prof. Dr. Ahmet Erhan Özdemir, Prof. Dr. Elif Çandır (corresponding author), Özay Baltaer, Durmuş Üstün, Department of Horticulture, Mustafa Kemal University, 31034 Antakya, Hatay, Turkey.
E-mail: ecandir@mku.edu.tr
Prof. Dr. Halit Yetişir, Department of Horticulture, Erciyes University, 38039 Melikgazi, Kayseri, Turkey.
Veysel Aras, Mustafa Ünlü, Alata Horticultural Research Institute, 33740 Erdemli, Mersin, Turkey
Ömer Arslan, Agriculture County Directorate, Silifke, Mersin, Turkey