DOI : 10.5958/0974-0112.2017.00017.2

Indian J. Hort. 74(1), March 2017: 71-74

Some biochemical characteristics of grafted watermelon

Aylin C. Oluk[*], Veysel Aras[**], Erdal Ağçam[***], Asiye Akyildiz[***] and Nebahat Sari[****]
Ministry of Food Agriculture and Livestock, Alata Horticultural Research Station Directorate, 33740 Mersin, Turkey

ABSTRACT

Grafting is an alternative approach to reduce crop damage resulting from soil-borne pathogens. This approach also increases plant abiotic stress tolerance, which in turn increases crop yield and quality. Therefore, the objective of this study was to determine the effect of grafting on watermelon quality parameters with the use of different rootstock combinations. Different morphological characteristics (yellow-red fleshed, with seed-seedless, striped rind and dark green rind) were grafted on rootstocks of Argentario (*Lagenaria* spp.) and Maximus (*Cucurbita maxima* × *C. moschata*). While the highest fructose, sucrose and soluble solids content were measured in Argentario/ TP84, TP84 had the highest glucose content. Total carotenoids content in watermelons ranged from 15.36 ± 2.78 to 104.51 ± 12.04 mg kg^{-1}. Argentario/ TP84 showed the highest level of lycopene (93.95 mg kg^{-1}) among cultivars and combinations. β-carotene content varied from 1.44 ± 0.01 to 3.76 ± 0.01 mg kg^{-1}. The highest ascorbic acid content was in Argentario/ TP84 (17.26 mg kg^{-1}), followed by Argentario/ 5299 (17.26 mg kg^{-1}). Grafting significantly increased soluble solids, sugars (fructose, glucose and sucrose), total carotenoids and ascorbic acid contents. Maximus/ Ant09 had the highest total carotenoids and lycopene content but lowest fructose, sucrose and soluble solids content on *C. maxima* × *C. moschata* combinations, whereas Argentario/ TP84 has the highest fructose, sucrose, soluble solids, total carotenoids, β-carotene, lycopene and ascorbic acid contents among cultivars and combinations. This study showed that use of bottle gourd (*Lagenaria* spp.) rootstock could enhance soluble solids, fructose, sucrose, lycopene and ascorbic acid contents in watermelon.

Key words: Ascorbic acid, pulp colour, grafting, total carotenoids, watermelon.

INTRODUCTION

Watermelon (*Citrullus lanatus* Thunb. Matsum and Nakai) is largely consumed as refreshing summer fruit throughout the Mediterranean region in Turkey. However, one of the most serious problems in its production is a decrease in yield due to soil-borne diseases, in particular *Fusarium* during successive cropping. Generally, grafting is used to reduce infections by soil-borne pathogens and to enhance the tolerance against abiotic stresses. One of the most effective methods in controlling *Fusarium* wilt of watermelon is crop rotation, *i.e.* it should not be cultivated for at least five years in the same infested field (Yetişir *et al.*, 15). On the other hand, grafting of susceptible varieties onto resistant rootstocks may enable the control of some soil-borne diseases and has positive impact on yield and quality. Beyond disease resistance, selected rootstocks are customarily evaluated for their effects on yield and fruit quality. Reports on rootstock-mediated effects on watermelon quality are available. However, the evaluation of quality has relied by convention on a simultaneous harvest of grafted and self-rooted plants, assuming a synchronized maturation. An inherent problem in such approach is that it overlooks the effect of grafting on fruit ripening behavior and may lead to inconsistent results (Davis *et al.*, 3). In this study, four watermelon cultivars having different morphological characteristics were grafted onto rootstocks of *Lagenaria* spp. and *C. maxima* × *C. moschata*.

MATERIALS AND METHODS

Four watermelon cultivars with different morphological characteristics (yellow fleshed, seedless, striped rind and dark greenblack rind) were grafted onto rootstocks of Argentario (*Lagenaria* spp./ bottle gourd) and Maximus (*C. maxima* × *C. moschata*/ inter-specific hybrid). Ungrafted varieties were used as control plants. TP84 and 5299 are striped rind and red pulp cultivars. Ant07 is slim-line striped rind and yellow fleshed. Ant09 (seedless) has dark green rind. The study was carried out in Alata Horticultural Research Station (Mersin-Turkey). Seedling growing and grafting were done by Antalya Fide (Antalya-Turkey) during March 2012. Antalya Fide grew non-grafted and grafted seedlings in modern greenhouses with hygienic

*Corresponding author's present address: Ministry of Food Agriculture and Livestock, Eastern Mediterranean Agriculture Research Institute, 01321 Adana, Turkey; E-mail: aylinoluk@yahoo.com
**Ministry of Food Agriculture and Livestock, Alata Horticultural Research Station Directorate, 33740 Mersin, Turkey
***University of Cukurova, Faculty of Agriculture, Department of Food Engineering, 01330 Adana, Turkey
****University of Cukurova, Faculty of Agriculture, Department of Horticulture, 01330 Adana, Turkey

conditions. Irrigation, spraying and climate conditions were automatically controlled by computer systems. Watermelon seedlings were transplanted on 12 April, 2012 into a sandy soil on black plastic mulch, with an in-row spacing of 300 cm and a between-row spacing of 70 cm in an open field in Mersin province on the Mediterranean coast of Turkey (latitude 36°37'59¨N, longitude 34°20'51¨E; decimal degrees 36.633094; 34.347624).

Fruit harvest was done when the tendril at the fruiting node was brown and dry. Three injury-free watermelon fruits were randomly hand-harvested for each cultivar and combination. The watermelons were quickly delivered to the laboratory and immediately cut longitudinally from the stem-end to the blossom-end through 1 cm to the right and 1 cm to the left of the ground spot. Samples were taken from the heart area (between locular and the fruit centre) of the watermelons. The soluble solids content (TSS) (°Brix) was determined by Atago hand-held refractometer. Sugars were extracted following modified method described by Bartolome *et al.* (1). Ascorbic acid determination was performed using the HPLC method and extraction procedure was followed according to Lee and Coates (6). Total carotenoids were extracted with the following modified version of the method described by Lee *et al.* (7). Carotenoids extraction and saponification procedures were carried out according to the previously reported method of Meléndez-Martínez *et al.* (10).

The software SPSS 16.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for analysis of variance (ANOVA) and Duncan's multiple comparison test in order to determine significant differences ($p<0.05$) between the treatments. Each experiment was repeated at least three times.

RESULTS AND DISCUSSION

The data on soluble solids content and total sugars of samples are given in Table 1. The effects of scion/ rootstock combinations on soluble solids content and sugar compounds were determined as significant ($p<0.05$). Soluble solids content was the highest in the 'Argentario/ TP84', while it was the lowest in 'Maximus/ Seedless'. Soluble solids content of 5299 and Ant09 grafted cultivars were lowered. Similarly, Miguel *et al.* (11) found no difference in soluble solids concentration of watermelon from scions grafted on to *C. maxima* × *C. moschata* hybrid rootstock compared with control. The results of Argentario rootstock grafted cultivars showed that they had tendency to increase the soluble solids content.

Fructose, glucose and sucrose were predominant sugars in watermelon. The concentrations of fructose, glucose and sucrose were determined higher for watermelon fruits grafted on to Argentario than on Maximus rootstock. Argentario/ TP84 had the highest content of fructose and sucrose, while Maximus/ Ant09 had the lowest content. It was reported that cultivars or maturity that causes higher fructose concentrations is a desirable feature since the relative sweetness of fructose is greater than that of sucrose (Elmstrom and Davis, 4). The predominant sugar was fructose in some red-fleshed watermelon cultivars (Proietti *et al.*, 12). Grafting onto Argentario rootstock had the highest fructose content. In addition, Argentario/ TP84 and Argentario/ Ant09 had more glucose contents than ungrafted controls. Furthermore, Argentario/

Table 1. Soluble solids content and sugars in watermelon cultivars grafted on different rootstocks.

Stionic combination	Soluble solids (%)	Fructose (g 100 g^{-1})	Glucose (g 100 g^{-1})	Sucrose (g 100 g^{-1})
Maximus/ Ant07	$11.07 \pm 0.05^{c*}$	3.74 ± 0.13^{cd}	1.87 ± 0.41^{de}	2.25 ± 0.01^{cd}
Maximus/ 5299	9.84 ± 0.04^{e}	3.49 ± 0.01^{ef}	1.26 ± 0.09^{hi}	2.28 ± 0.17^{bd}
Maximus/ Ant09	9.45 ± 0.01^{f}	3.12 ± 0.18^{h}	1.74 ± 0.03^{ef}	1.66 ± 0.27^{f}
Maximus/ TP84	11.06 ± 0.05^{c}	3.72 ± 0.21^{cd}	1.61 ± 0.10^{fg}	2.34 ± 0.02^{bc}
Argentario/ Ant07	9.72 ± 0.04^{e}	3.37 ± 0.08^{fg}	1.27 ± 0.09^{hi}	1.93 ± 0.04^{e}
Argentario/ 5299	10.86 ± 0.02^{d}	3.85 ± 0.04^{bc}	1.09 ± 0.05^{i}	2.48 ± 0.01^{b}
Argentario/ Ant09	12.16 ± 0.02^{b}	4.06 ± 0.03^{a}	2.31 ± 0.04^{c}	2.49 ± 0.76^{b}
Argentario/ TP84	13.70 ± 0.01^{a}	4.12 ± 0.04^{a}	2.66 ± 0.06^{b}	3.76 ± 0.02^{a}
Ant07	9.58 ± 0.01^{f}	3.22 ± 0.01^{gh}	1.46 ± 0.01^{gh}	1.89 ± 0.04^{e}
5299	10.74 ± 0.04^{d}	3.58 ± 0.02^{de}	1.68 ± 0.06^{eg}	2.28 ± 0.05^{bd}
Ant09	11.21 ± 0.05^{c}	3.95 ± 0.05^{ab}	1.99 ± 0.05^{d}	2.43 ± 0.23^{bc}
TP84	10.27 ± 0.01^{de}	3.96 ± 0.05^{ab}	2.99 ± 0.01^{a}	2.07 ± 0.01^{de}

*Means ± SD within a column with no common superscript differ ($p<0.05$)

TP84 had higher sucrose concentration than other rootstocks and control plants. It was concluded that soluble solids, fructose and sucrose contents were improved in grafted watermelon onto Argentario rootstock. Sucrose appears only after initiation of colour development (about 30% fruit growth) in seeded heirloom varieties and in *Cucumis melo* (Elmstrom and Davis, 4), but was found to be present at all growth stages in grafted and non-grafted plants. Acid invertase activity was high during the first third of watermelon fruit development, and then had reduced activity during the last five days of ripening. Sucrose synthase activity was moderately high in the first third of fruit development then remained low. Sucrose phosphate synthase increased during the second third of fruit development, and fell in the last five days of ripening (Liu *et al*., 9). The increase in sucrose of grafted plants was accompanied by an increase of sucrose phosphate synthase and sucrose synthase activities (Xu *et al*., 14). In addition, it appears that sugar accumulation in mature fruit varied with rootstocks.

The effects of grafting on total carotenoids content were determined significant (Table 2). Argentario/ TP84 and Argentario/ 5299 had higher total carotenoids, β-carotene and lycopene contents than other rootstcoks and control plants. The total carotenoids, β-carotene and lycopene in fruits of the ungrafted plants were 6.03-68.99 mg kg^{-1}, 1.78-2.80 mg kg^{-1} and 2.89-65.77 mg kg^{-1}, respectively. In the graft combination of Maximus rootstock varied from 15.36-73.89 mg kg^{-1}, from 1.76 to 2.97 mg kg^{-1} and from 10.27 to 69.47 mg kg^{-1}, respectively. Grafted watermelon fruits onto Argentario had 3.68-104.51 mg kg^{-1} of total carotenoids,1.44-3.76 mg kg^{-1} of β-carotene and 1.73-93.95 mg kg^{-1} of lycopene. Based on the results it can be concluded that the Argentario rootstock was more effective than Maximus in terms of total carotenoids contents. According to previous studies on different grafted rootstocks such as *C. maxima* Duchesne× *C. moschata* Duchesne (Proietti *et al*., 12) and local bottle gourd rootstocks (Candır *et al*., 2), lycopene content of grafted watermelon obtained were higher than on the non-grafted control.

Liu *et al*. (8) reported that grafted seeded watermelon on five different rootstocks of *L. siceraria* or *C. ficifolia*. They noted higher amino acids and carotene content in fruit of grafted vs. non-grafted plants. Kyriacou and Soteriou (5) examined four diploid cultivars grown non-grafted or grafted onto three *Cucurbita maxima* × *C. moschata* rootstocks. The lycopene content of grafted watermelons was higher than the non-grafted control. It is not known how grafting could ncrease the carotenoids content of fresh on plants grafted.

The highest ascorbic acid content was determined in Argentario/ TP84 and followed by yellow Ant07 cultivars (Table 2). The ascorbic acid contents varied from 0.63–5.44 mg kg^{-1} in ungrafted watermelons. For grafted cultivars onto Argentario and Maximus rootstocks, the ascorbic acid contents ranged from 0.74-17.26 and 0.51-1.01 mg kg^{-1}, respectively. Ascorbic acid concentration was significantly affected by grafting onto Argentario. Ascorbic acid content of watermelons increased due to grafting. Proietti *et al.*

Table 2. Total carotenoids, carotenoids and ascorbic acid in watermelon cultivars grafted on different rootstocks.

Stionic combination	Total carotenoids (mg kg^{-1})	β-carotene (mg kg^{-1})	Lycopene (mg kg^{-1})	L-ascorbic acid (mg kg^{-1})
Maximus/ Ant07	15.36 ± 2.78^{g*}	2.97 ± 0.01^{b}	10.27 ± 0.12^{h}	0.51 ± 0.05^{fg}
Maximus/ 5299	54.29 ± 11.82^{f}	1.76 ± 0.01^{f}	49.06 ± 1.32^{g}	2.96 ± 0.05^{d}
Maximus/ Ant09	73.89 ± 13.6^{b}	2.88 ± 0.18^{b}	69.47 ± 8.41^{b}	0.35 ± 0.06^{g}
Maximus/ TP84	57.13 ± 5.72^{f}	2.63 ± 0.01^{c}	53.68 ± 0.13^{f}	1.10 ± 0.07^{e}
Argentario/ Ant07	3.68 ± 0.71^{i}	1.44 ± 0.01^{g}	1.73 ± 0.10^{j}	0.74 ± 0.01^{f}
Argentario/ 5299	76.88 ± 12.95^{b}	3.67 ± 0.24^{a}	71.24 ± 7.55^{b}	11.71 ± 0.28^{b}
Argentario/ Ant09	71.77 ± 12.84^{c}	2.10 ± 0.05^{e}	64.85 ± 2.01^{bd}	1.04 ± 0.04^{e}
Argentario/ TP84	104.51 ± 12.04^{a}	3.76 ± 0.01^{a}	93.95 ± 0.96^{a}	17.26 ± 0.28^{a}
Rootstock				
Ant07	6.03 ± 0.05^{h}	2.38 ± 0.05^{d}	2.89 ± 0.24^{i}	0.63 ± 0.09^{f}
5299	68.99 ± 10.72^{d}	2.80 ± 0.28^{bc}	65.77 ± 5.46^{bc}	5.44 ± 0.31^{c}
Ant09	62.59 ± 10.08^{e}	1.78 ± 0.01^{f}	58.81 ± 1.10^{ce}	1.01 ± 0.01^{e}
TP84	62.71 ± 8.03^{e}	2.58 ± 0.15^{cd}	56.29 ± 6.74^{df}	2.91 ± 0.03^{d}

*Means ± SD within a column with no common superscript differ (p<0.05).

(12) reported that dehydroascorbate and total vitamin C contents for grafted mini-watermelon plants were higher by 13 and 7%, respectively, than those from ungrafted plants. Qin *et al.* (13) reported that the vitamin C content of the fruit plants on grafted from the combined bottle gourd and pumpkin rootstock was higher than that of plants grafted with either bottle gourd or pumpkin alone.

In conclusion, the results showed that scion/rootstock combinations have significant effect on biochemical characteristics of grafted watermelon. Rootstock-scion combinations has the highest increase in sugar and lycopene contents in watermelon. It could be concluded that the most important biochemical properties of watermelons grafted on the *Lagenaria* spp. are better than those grafted on to the *C. maxima* × *C. moschata*. Our study demonstrated that under convenient circumstances, and using specific rootstock/ scion combinations, the grafting treatment can enhance fruit quality.

REFERENCES

1. Bartolome, A.P., Ruperez, P. and Fuster, C. 1995. Pineapple fruit: morphological characteristics, chemical composition and sensory analysis of red Spanish and Smooth Cayenne cultivars. *Food Chem.* **53**: 75-79.

2. Candır, E., Yetişir, H., Karaca, F. and Durmuş, U. 2013. Phytochemical characteristics of grafted watermelon on different bottle gourds (*Lagenaria siceraria*) collected from the Mediterranean region of Turkey. *Turkish J. Agric. Forest.* **37**: 443-56.

3. Davis, A.R., Webber, C.L., Perkins-Veazie, P., Ruso, V., L´opez-Galarza, S. and Sakata, Y. 2008. A review of production systems on watermelon quality. **In**: M. Pitrat (Ed.), *Proceedings of the IXth EUCARPIA Meeting on Genetics and Breeding of Cucurbitaceae*, INRA, Avignon (France), pp. 515-20.

4. Elmstrom, G.W. and Davis, P.L. 1981. Sugars in developing and mature fruits of several watermelon cultivars. *J. American Soc. Hort. Sci.* **106**: 330-33.

5. Kyriacou, M.C. and Soteriou, G. 2015. Quality and postharvest performance of watermelon fruit in response to grafting on interspecific cucurbit rootstocks. *J. Food Quality*, **38**: 21-29.

6. Lee, H.S. and Coates, G.A. 1999. Vitamin C in frozen, fresh squeezed, unpasteurized, polyethylene-bottled orange juice: A storage study. *Food Chem.* **65**:165-68.

7. Lee, H.S., Castle, W.S. and Coates, G.A. 2001. High-performance liquid chromatography for the characterization of carotenoids in the new sweet orange (Earlygold) grown in Florida, USA. *J. Chromatogr. A* **913**: 371-77.

8. Liu, R.Q., Zhang, H.M., Xu, J.H., Huang, D.F. and Yao, F.J. 2003. Effects of rootstocks on growth and fruit quality of grafted watermelon. *J. Shanghai Jiaotong Univ. Agril. Sci.* **4**: 289-94.

9. Liu, H.Y., Zhu, Z.J., Diao, M. and Guo, Z.P. 2006. Characteristic of the sugar metabolism in leaves and fruits of grafted watermelon during fruit development. *Plant Physiol. Comm.* **42**: 835-40.

10. Meléndez-Martínez, A.J., Vicario, I.M. and Heredia, F.J. 2007. Rapid assesments of vitamin activity through objective color measurements for the quality control of orange juices with diverse carotenoid profiles. *J. Agric. Food Chem.* **55**: 2808-15.

11. Miguel, A., Maroto, J.V., San Bautista, A., Baixauli, C., Cebolla, V., Pascual, B., L´opez-Galarza, S. and Guardiola, J.L. 2004. The grafting of triploid watermelon is an advantageous alternative to oil fumigation. *Scientia Hort.* **103**: 9-17.

12. Proietti, S., Rouphael, Y., Colla, G., Cardarelli, M., De Agazio, M., Zacchini, M., Rea, E., Moscatello, S. and Battistelli, A. 2008. Fruit quality of mini-watermelon as affected by grafting and irrigation regimes. *J. Sci. Food Agric.* **88**: 1107-14.

13. Qin, Y., Yang, C., Xia, J., He, J., Ma, X., Yang, C., Zheng, Y., Lin, X., He, Z., Huang, Z. and Yan, Z. 2014. Effects of dual/threefold rootstock grafting on the plant growth, yield and quality of watermelon.*Not. Bot. Hort. Agrobor.* **42**: 495-500.

14. Xu, C.Q., Li, T.L. and Qi, H.Y. 2006. Effects of grafting on development, carbohydrate content, and sucrose metabolizing enzymes activities of muskmelon fruit. *Acta Hort. Sinica*, **33**: 773-78.

15. Yetişir, H., Özdemir, A.E., Aras, V., Çandır,E. and Aslan, O. 2013. Rootstocks effect on plant nutrition concentration in different organs of grafted watermelon. *Agric. Sci.* **4**: 230-37.

Received : March, 2016; Revised : January, 2017; Accepted : February, 2017