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Rootstock potential of Turkish *Lagenaria siceraria* germplasm for watermelon: plant growth, yield and quality

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Abstract: The rootstock potential of 21 bottle gourds (*Lagenaria siceraria*) collected from the Mediterranean region (Turkey) was investigated for watermelon with regard to plant growth, yield, and fruit quality. The Crimson Tide watermelon cultivar was used as a scion and 2 commercial rootstocks (*L. siceraria*) were also used for comparison. In greenhouse conditions, the survival rate of grafted plants and the effect of rootstocks on plant growth were determined. The grafted plants were planted under low tunnels in early spring and the effects of the rootstocks on early yield, total yield, and fruit quality were evaluated. The survival rates of the grafted plants varied from 83% to 100%. Survival rates of those with commercial rootstocks and local rootstocks were similar. Plants grafted onto 20-02, 31-09, 31-43, 35-01, and 46-03 were more vigorous than ungrafted control plants. Compared to the control plants, grafted plants had 37% to 80% higher plant dry weight. All of the grafted plants except CT/Macis produced a higher yield than the control plants. The plants grafted onto 6 of the local rootstocks had significantly greater total yields than those grafted onto the commercial rootstocks. Among the local bottle gourd landraces tested, the 01-16, 07-45, 20-06, 31-09, 31-15, and 46-03 were found to be promising genotypes with regard to total yield. Early yield was not significantly affected by rootstock. The quality parameters of the fruits harvested from the grafted and control plants were found to be similar except for a limited number of graft combinations. It was concluded that germplasm from Turkish bottle gourds has a high rootstock potential for watermelon with regard to the investigated parameters.

Key words: Bottle gourd, grafting, quality, yield

Türkiye'deki *Lagenaria siceraria* gen kaynaklarının karpuz için anaçlık potansiyeli: bitki gelişimi, verim ve kalite

Özet: Bu araştırmada, Akdeniz havzasından toplanmış olan 21 su kabağı (*L. siceraria*) genotipinin karpuza bitki gelişimi, verim ve kalite açısından anaçlık potansiyeli araştırılmıştır. Kalem olarak Crimson Tide karpuz çeşidi ve karşılaştırma amacı ile 2 hibrit su kabağı anacı kullanılmıştır. Serada aşı tutma oranı tespit edilmiş ve aşılanmış bitkiler saksılarda yetiştirilerek anaçların bitki büyümesine etkisi belirlenmiştir. Aşılanan fideler erken ilkbaharda alçak tünel

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altına dikilmiş ve anaçların erkenci verim, toplam verim, pazarlanabilir verim ve meyve kalitesi üzerindeki etkileri araştırılmıştır. Aşı tutma oranı anaçlara bağlı olarak % 83 ile % 100 arasında değişmiştir. Ticari anaçların ve yerel anaçların aşı tutma oranı benzer bulunmuştur. 20-02, 31-09, 31-43, 35-01 ve 46-03 yerel anaçları üzerine aşılanmış olan bitkiler kontrol bitkilerinden daha fazla gelişmiştir. Aşılı bitkilerdeki kuru ağırlık artışı anaca bağlı olarak % 37 ile % 80 oranlarında olmuştur. Macis hariç, aşılı bitkilerden kontrol bitkilerine göre daha yüksek verim alınmıştır. Yerel anaçların bazıları ticari anaçlardan daha yüksek toplam verim değerlerine sahip olmuştur. Yerel anaçlar arasında yüksek verim değerine sahip olan 01-16, 07-45, 20-06, 31-09, 31-15 ve 46-03 no'lu genotipler ön plana çıkmıştır. Erkenci verim bakımından anaçlar arasında istatistiksel anlamda fark bulunmamıştır. Kalite parametreleri açısından sınırlı sayıdaki aşı kombinasyonu hariç aşılı karpuz bitkilerinden alınan meyveler ile kontrol bitkilerinden alınan meyveler benzer bulunmuştur. Yapılan çalışma sonucunda, araştırılan parametreler açısından Türkiye'nin su kabağı gen kaynağının karpuza anaçlık potansiyelinin yüksek olduğu sonucuna varılmıştır.

Anahtar sözcükler: Aşılama, kalite, su kabağı, verim

Introduction

Bottle gourd [*Lagenaria siceraria* (Molina) Standl.] was one of the first plant species to be domesticated for human use, providing food, medicine, and various utensils and instruments that could be made from the large, hard-shelled fruit. The 5 wild species of bottle gourd are native to the northern half of Africa, with *L. sphaerica* (Sond.) Naudin and *L. breviflora* (Benth.) Roberty occurring as far south as South Africa and Zimbabwe, respectively (Decker-Walters et al. 2004).

Turkey is not the genetic origin of *L. siceraria*, but the landraces of bottle gourd show significant diversity, particularly in fruit size and shape. However, it is not an economically grown plant species in Turkey (Yetişir et al. 2008).

Bottle gourd fruits are generally grown as a vegetable in Africa and Asia. Immature fruits are consumed by boiling, frying, or stuffing like the fruit of *Cucurbita pepo*. Shoots, tendrils, and leaves are also cooked, and the seeds are used for oil extraction or for cooking. The tendrils and young leaves are also utilized for some medicinal purposes (Tindall 1983). Bottle gourd has also been used routinely as a source of rootstock for watermelon and other cucurbit crops in some Asian and European countries to reduce the incidence of soil-borne diseases and to promote the vigor of the root system of the crop under conditions of low temperature (Lee and Oda 2003). Watermelon was first grafted onto bottle gourd against *Fusarium oxysporum* f. sp. *niveum* (*Fon*) in Korea and Japan in the late 1920s (Lee 1994). *L. siceraria* is one of the gourd species used as rootstock for watermelon and it shows a high compatibility rate with watermelon (Lee 1994; Oda 1995; Yetisir and Sari 2003).

Turkey is one of the world's most important watermelon-producing countries after China, with 3,800,000 t year^{-1} (FAO 2009). Watermelon cultivation has been carried out intensively for many years in the watermelon production areas of Turkey. One of the most serious problems facing watermelon production in this country is the decrease in yield due to soil-borne diseases, in particular fusarium, and to successive cropping (Yetisir and Sari 2003). The traditional way to deal with the problem posed by fusarium infestation has been the implementation of a crop rotation including fusarium-resistant species. This approach was useful and practicable in extensive watermelon production. However, in intensive out-of-season production, the limited available field for watermelon production forces the grower to repeat the same species almost every year, which can aggravate the problem caused by the fusarium infestation. In addition, the development of new cultivars that are resistant to disease is time-consuming and enhances the chances of the resistant cultivars becoming susceptible to new races of pathogens. On the other hand, grafting onto resistant rootstocks may enable the control of soil-borne diseases and have positive impacts on plant growth, yield, and quality (Lee 1994; Oda 1995; Lee and Oda 2003). Watermelon has been widely grafted to control soil-borne disease such as fusarium wilt (Yetisir and Sari 2003; Lopez-Galarza et al. 2004) and to promote the mineral nutrient uptake (Pulgar et al. 2000), but the objectives of grafting have increased significantly over the years. These days, for instance, grafting can be used to improve resistance against low (Bulder et al. 1990) and high (Rivero et al. 2003) temperatures, to combat iron chlorosis in calcareous soils (Romero et al. 1997), to improve the salinity tolerance of plants (Yetisir and Uygur 2010), to enhance nutrient absorption (Ruiz et al. 1997), and to improve water use (Cohen and Naor 2002).

Watermelons are produced both in open fields and under low plastic tunnels in Turkey. Several commercial trials using grafted watermelon seedlings have been conducted in multiple locations across the country to increase yield and quality or to demonstrate grafting as an alternative to soil fumigants. As a result of these studies, the use of grafted watermelon seedlings has become quite widespread in Turkey and the number of grafted seedlings planted increased about 13-fold during the last decade (Yetişir et al. 2010). At present, rootstocks for watermelon are being imported from other countries because there are no rootstocks bred for watermelon in Turkey. Turkey has a rich genetic diversity of *L. siceraria*. In a previous study, we collected and evaluated 210 genotypes of *L. siceraria* from ecologically different regions of Turkey. The rootstock potential of Turkish bottle gourd germplasm was evaluated and it was found that Turkish *L. siceraria* germplasm has powerful rootstock potential for protecting watermelons from fusarium wilt; it is a good resource for rootstock breeding programs (Yetişir et al. 2007). In our previous work, however, the volumes of the pots were small (2 L) and the effects of the rootstocks on plant growth performance could be observed only for a limited time; the effect of this rootstock on yield and fruit quality was not investigated. Therefore, the present study was established to determine the rootstock potential of a subset of the Turkish bottle gourd germplasm for watermelon in terms of the plant growth, yield and fruit quality.

Materials and methods

Plant materials and culture conditions

In the present study, 21 bottle gourd genotypes were chosen as representatives of Turkish *L. siceraria* germplasm for rootstock, based on the work of Yetişir et al. (2008). The commercial *Lagenaria* hybrid rootstocks Argentario and Macis were also used for comparison (Table 1). Crimson Tide (CT) watermelon cultivar was used as a scion. Seeds of CT were sown in a peat and perlite mixture (1:1 v/v) in plug trays (cell volume: 50 mL) in an unheated greenhouse (36°19′30.75″N, 36°11′40.82″E) on 15 January 2008. For rootstocks, 150 seeds per genotype were sown in a peat and perlite mixture (2:1 v/v) in plug trays (cell volume: 50 mL) for grafting.

Grafting and survival rate

The hole-insertion grafting technique was used and plants were grafted following the procedure described by Lee (1994) and Lee and Oda (2003). Seedlings were grown in an unheated greenhouse under plastic tunnels. A total of 100 seedlings were grafted from each bottle gourd genotype. The live grafted plants were counted 15 days after grafting and the survival rate was expressed as a percentage of the total number of the grafted plants.

Plant growth experiment

On 15 March 2008, 12 grafted plants from each rootstock genotype were transplanted in a greenhouse to 8-L pots filled with a peat and perlite mixture (1:1 v/v). Ungrafted CT watermelon cultivar was used as the control. The experimental design was a randomized complete block design. Each rootstock was replicated 3 times with 4 plants in each replication. Plants were irrigated at 2-day intervals with the same amount of water. Plants were irrigated once a week with a nutrient solution prepared according to the method of Yetişir et al. (2006). Plants were harvested 6 weeks after transplanting. The leaf number (leaf plant^{-1}), leaf area (cm^2) (LI-COR 3100 Area Meter, LI-COR, Lincoln, NE, USA), shoot (shoot and leaves) dry weight (g plant^{-1}), and root dry weight (g plant^{-1}) were determined. After the roots were washed and cleaned of growth media, the roots and shoots were placed in an oven with circulating air at 70 °C for 48 h and weighed for dry weight.

Determination of rootstock effect on yield and fruit quality

The grafted and control plants were transplanted under low plastic tunnels in Adana (37°01′50.57″N, 35°22′00.15″E); the tunnels were removed when the air temperature was suitable for watermelon (22-25 °C). Fertilizer was applied at a rate of 180 kg N ha^{-1}, 200 kg P_2O_5 ha^{-1}, and 180 kg K_2O ha^{-1} (Yetisir and Sari 2003). Any necessary micronutrients were applied.

All of the P was applied before planting. Nitrogen and potassium were divided into 3 equal portions and applied before planting, 20 days after planting, and 40 days after planting. The experimental design was randomized complete blocks. Each treatment was replicated 4 times, with 15 plants in each replicate. Seedlings were transplanted in single rows spaced 3.0 m apart with 0.6 m between plants. Water was applied by drip irrigation. Ripe fruits with completely dried stipule and tendrils on the same node as the fruit were harvested between 6 and 12 June 2008 and between 20 and 30 June 2009. The total yield (t ha^{-1} and kg $plant^{-1}$), early yield (t ha^{-1}), and marketable yield (%) were evaluated. In order to assess quality, 5 fruits from each replicate were randomly chosen to determine the fruit weight (g), rind thickness (mm), flesh color, flesh firmness (newtons, N), taste (1-9 scale), and total soluble solid content (TSS) (%). Fruit flesh color was measured as reflected in the CIELAB ($L^*a^*b^*$) color space using a CR-300 Minolta Chroma Meter (Konica Minolta, Osaka, Japan). 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). Flesh firmness of the heart portion of the watermelon was determined with a fruit hardness tester (Model 510-1 FHR-5, Nippon Optical Works Co. Ltd., Tokyo, Japan). This involved measuring the force in kilograms required for an 11-mm probe to penetrate the cut surface to a depth of 5 mm at 3 locations in the mesocarp tissue; the result was then converted to newtons. TSS content was assessed in the juice obtained from 5 fruits per replicate after slicing and removing rinds and seeds with a digital refractometer (Atago PAL-3, Atago, Tokyo, Japan) at 24 °C. A trained panel consisting of 10 people evaluated the sensory quality of the watermelons using a hedonic scale of 1 (disliked extremely) to 9 (liked extremely). The study was performed over a 2-year period, in 2008 and 2009. Data are represented as the mean of 2 experimental years.

Statistical analysis

The data were analyzed as a factorial experiment in a completely randomized block design by ANOVA using SAS software from the SAS Institute (SAS 2006). Mean separation was performed with Duncan's test at $P < 0.05$ and $P < 0.01$ levels using SAS's Proc GLM procedure.

Results

The survival rate of graft combinations was significantly affected by the rootstock. Survival rates ranged from 83% to 100%, with 9 of the local bottle gourd landraces and both of the commercial rootstocks (01-16, 01-17, 07-42, 20-06, 31-08, 31-09, 33-45, 35-01, 47745, Macis, and Argentario) having 100% survival rates. The lowest survival rate was recorded in 46-03 at 83.3% (Table 1).

Main stem lengths showed significant differences based on the rootstock (Table 1). Plants grafted onto 20-02, 31-09, 31-43, 35-01, and 46-03 had significantly longer main stems than the ungrafted control plants. Other grafted plants showed similar main stem lengths to that of the control plants. The ungrafted control plants had main stems measuring 98.8 cm on average, whereas the overall mean main stem length of the grafted plants was 118 cm. Leaf number was also significantly influenced by rootstocks, and all of the grafted plants had a higher number of leaves per plant than the ungrafted control plants. In comparison to the ungrafted control plants, increases in leaf number varied from 51% to 100% based on the rootstocks. Local rootstocks and commercial rootstocks demonstrated a similar number of leaves per plant. The leaf area was also affected significantly by rootstocks. Plants grafted onto 01-17, 07-04, 31-08, 31-09, 31-15, 33-35, 33-41, 35-01, 33-41, 46-03, 47745, and Macis showed significantly higher leaf areas than that of the control plants (Table 1).

Shoot growth was significantly affected by rootstock and all of the grafted plants showed more plant growth than the ungrafted control plants. The graft combinations CT/46-03, CT/01-16, and CT/01-17 produced higher shoot dry weights, while the ungrafted control plants had the lowest shoot fresh weight at 13.8 g/$plant^{-1}$. Among the grafted plants, 3 local rootstocks (01-16, 01-17, and 46-03) produced

Table 1. Survival rate, main stem length, leaf number and leaf area, and shoot and root dry weight of watermelon grafted onto different *L. siceraria* landraces 45 days after transplanting.

Graft combinations	Survival rate (%)	Main stem length (cm)	Leaf number (per plant)	Leaf area (cm^2)	Shoot dry weight (g $plant^{-1}$)	Root dry weight (g $plant^{-1}$)
CT	-----	98.8 d	37.8 d	1476.0 b	13.68 g	1.50 f
CT/01-16	100.0 a	113.5 a-d	61.0 abc	2275.8 ab	24.06 a	2.29 abc
CT/01-17	100.0 a	118.3 a-d	76.2 a	2596.7 a	23.87 a	2.01 b-f
CT/07-04	96.9 abc	127.0 a-d	75.8 a	2824.2 a	22.13 bc	2.78 a
CT/07-06	92.7 b-e	111.7 a-d	65.0 abc	2099.2 ab	19.86 ef	1.79 c-f
CT/07-42	100.0 a	123.7 a-d	68.2 abc	2399.0 ab	20.68 cde	2.06 b-e
CT/07-45	90.6 de	111.3 a-d	59.5 bc	2306.5 ab	21.69 cd	2.05 b-e
CT/09-01	95.8 a-d	123.0 a-d	68.8 abc	2373.0 ab	21.66 cd	2.20 bcd
CT/20-02	95.8 a-d	134.2 a	55.7 c	2239.0 ab	20.05 ef	2.50 ab
CT/20-06	100.0 a	122.8 a-d	59.2 bc	2318.7 ab	20.25 de	2.06 b-e
CT/31-08	100.0 a	124.2 a-d	66.0 abc	2474.7 a	22.17 bc	2.05 b-e
CT/31-09	100.0 a	129.2 ab	65.0 abc	2570.8 a	23.04 ab	2.18 bcd
CT/31-15	91.7 cde	99.2 cd	65.2 abc	2445.8 a	18.74 f	1.73 def
CT/31-43	99.0 ab	127.5 abc	70.3 abc	2360.0 ab	22.06 bc	2.27 a-d
CT/33-02	99.0 ab	104.7 bcd	62.5 abc	2268.5 ab	21.82 c	2.15 bcd
CT/33-35	99.0 ab	115.8 a-d	68.2 abc	2676.7 a	20.78 cde	2.11 bcd
CT/33-41	88.5 ef	108.0 a-d	73.5 ab	2522.3 a	20.23 de	1.92 c-f
CT/33-45	100.0 a	113.3 a-d	64.2 abc	2231.8 ab	23.41 ab	1.80 c-f
CT/35-01	100.0 a	132.3 ab	69.3 abc	2656.8a	21.89 c	2.28 a-d
CT/46-03	83.3 f	130.7 ab	70.5 abc	2908.3 a	24.68 a	1.82 c-f
CT/48-07	99.0 ab	117.7 a-d	66.8 abc	2321.2 ab	23.34 ab	2.24 bcd
CT/47745	100.0 a	121.7 a-d	69.3 abc	2504.8 a	20.69 cde	1.53 ef
CT/Macis	100.0 a	122.0 a-d	60.5 abc	2529.3 a	22.22 bc	1.97 b-f
CT/Argentario	100.0 a	108.5 a-d	60.5 abc	2326.1 ab	22.08 bc	2.10 bcd
	**	*	**	*	**	**
Control	------	98.8	37.8	1476.0	13.68	1.50
Overall mean	97.0	118.3	65.0	2404.4	21.46	2.06
Local RS mean	96.7	119.5	66.7	2446.4	21.76	2.09
Com. RS mean	100.0	115.3	60.5	2427.7	22.15	2.03

* and ** indicate values that are significant at 5% and 1%, respectively. Means not followed by the same letter within a column are significantly different ($P < 0.05$ and $P < 0.01$) according to Duncan's multiple range test.
CT: Crimson Tide, RS: rootstock, Com.: commercial

higher shoot dry weights than the commercial rootstocks, whereas 5 local rootstocks (07-06, 20-02, 20-06, 31-15, and 33-41) produced lower shoot dry weights than the commercial rootstocks. The increase rate in the shoot dry weight in comparison to control plants varied from 37% to 80% among the rootstocks (Table 1).

Root growth showed significant differences based on rootstock genotypes. The weakest root development was determined in the ungrafted control plants. In all, 14 graft combinations, including local rootstocks and Argentario, resulted in higher root dry weights than those found in the ungrafted control plants. A further 7 graft combinations with local rootstocks and Macis had root dry weights that were similar to those of the control plants. The 07-04 showed better root growth than Argentario and Macis (Table 1).

Total yield was significantly affected by the rootstock and, except for CT/Macis, all of the grafted plants produced significantly more yield than the ungrafted control. Graft combinations of CT/46-03, CT/20-06, CT/07-45, CT/31-09, CT/31-15, and CT/01-16 produced significantly higher yields than the commercial rootstocks (Table 2). Early yield was not significantly affected by rootstocks, although

Table 2. Yield parameters of watermelon grafted onto different *L. siceraria* landraces.

Graft combinations	Total yie (t ha^{-1})	Early yield (t ha^{-1})	Yield per plant (kg)	Marketable yield (%)
CT	40.5 i	10.5	6.30 i	89.4 f
CT/01-16	72.5 a-e	12.0	13.00 a-e	98.0 a-e
CT/01-17	66.0 c-g	12.5	11.75 c-g	98.2 a-e
CT/07-04	67.5 c-g	14.0	12.50 b-f	99.5ab
CT/07-06	64.5 c-g	13.0	11.65 c-g	99.1 abc
CT/07-42	71.5 b-f	13.0	12.85 b-f	99.3 abc
CT/07-45	75.5 abc	13.5	13.45 abc	99.0 abc
CT/09-01	63.0 c-g	14.0	11.25 c-g	97.1 b-e
CT/20-02	60.0 e-h	12.0	10.80 e-h	97.8 a-e
CT/20-06	80.0 ab	17.0	14.40 ab	97.6 a-e
CT/31-08	65.0 c-g	13.0	11.70 c-g	96.9 cde
CT/31-09	73.0 a-d	14.5	13.20 abc	99.7 a
CT/31-15	72.5 a-e	15.0	13.10 a-d	97.9 a-e
CT/31-43	62.5 d-h	11.0	11.30 c-g	98.3 a-d
CT/33-02	60.5 d-h	8.0	10.90 d-h	95.8 e
CT/33-35	60.0 e-h	10.5	10.75 fgh	97.7 a-e
CT/33-41	69.0 b-f	10.0	12.40 b-f	99.2 abc
CT/33-45	63.5 c-g	10.0	11.35 c-g	96.2 de
CT/35-01	67.5 c-g	10.5	12.10 c-g	97.8 a-e
CT/46-03	84.0 a	15.5	15.05 a	98.1 a-e
CT/48-07	66.5 c-g	11.0	12.00 c-g	98.5 a-d
CT/47745	55.5 gh	10.5	10.00 gh	99.6 a
CT/Macis	50.5 hi	10.5	9.05 h	98.3 a-d
CT/Argentario	59.5 fgh	09.5	10.65 fgh	97.2 a-d
	**	**ns**	**	**
Control	40.5	10.5	6.30	89.4
Overall mean	65.4	12.1	11.73	97.7
Local RS mean	67.6	12.4	12.17	98.1
Com. RS mean	55.0	10.0	9.85	97.8

** indicates values significant at 1%; ns: not significant. Means not followed by the same letter within a column are significantly different ($P < 0.01$) according to Duncan's multiple range test.

CT: Crimson Tide, RS: rootstock, Com.: commercial the yield per plant was influenced by rootstocks to a significant degree. All of the grafted plants produced significantly more yield per plant than the ungrafted control plants. Combinations of CT/46-03, CT/20-06, CT/07-45, CT/31-09, CT/31-15, and CT/01-16 produced significantly more yield per plant than the commercial rootstocks. When compared to the control, the increase in yield per plant varied from 44% to 138%. Marketable yield was significantly increased by grafting and was over 95% in the grafted plants. All of the grafted plants in this study showed a higher marketable yield than the control plants (Table 2).

Plants grafted onto *Lagenaria*-type rootstocks produced larger fruit than the control plants, with the exception of 20-02 (Table 3). The control plants and CT/20-02 graft combination had the smallest fruits at 5639 and 6248 g, respectively. The increase rate of fruit size ranged from 11% (CT/20-02) to 46% (CT/35-01) based on rootstocks. CT/35-01 had larger fruit than CT/Argentario, while its fruit weight was similar to that of CT/Macis. Rootstocks significantly affected rind thickness and, except for CT/20-06 and CT/46-03, all of the grafted plants produced fruit with a thicker rind than the control plants. The plants grafted onto 35-01, 31-15, 31-09, 31-43, and

Table 3. Fruit quality characteristics of watermelon grafted onto different *L. siceraria* landraces.

Graft combinations	Fruit weight (g)	Rind thickness (mm)	Fruit flesh firmness (N)	Total soluble solids (%)	Taste (1-9 scale)	C*	*h*°
CT	5639.0 f	14.8 j	7.6	10.8 cd	8.4 abc	33.5 a-e	41.4 a-e
CT/01-16	7278.5 b-e	17.0 f-i	7.8	10.8 cd	8.3 abc	34.8 a-d	40.8 a-g
CT/01-17	7856.5 a-e	18.5 b-f	7.4	11.1 a-d	8.7 abc	33.5 a-e	39.4 b-i
CT/07-04	8096.5 ab	16.7 ghi	7.3	11.2 a-d	8.7 abc	31.9 cde	38.8 b-j
CT/07-06	7770.5 a-e	16.5 hi	7.4	11.4 a-d	8.4 abc	30.6 ef	37.7 e-j
CT/07-42	8046.0 abc	17.8 d-h	7.6	11.8 abc	8.4 abc	35.9 a	42.3 ab
CT/07-45	7306.0 b-e	17.6 d-i	7.6	11.4 a-d	8.2 bc	32.4 a-e	38.8 b-j
CT/09-01	7791.5 a-e	17.8 d-h	7.2	12.0 ab	8.4 abc	32.3 a-e	38.0 d-j
CT/20-02	6248.0 f	17.1 e-i	8.0	11.0 bcd	7.6 d	35.9 a	43.8 a
CT/20-06	7429.0 a-e	16.3 hij	7.9	11.2 a-d	8.2 bc	33.6 a-e	41.9 abc
CT/31-08	7646.5 a-e	17.4 d-i	7.7	11.5 a-d	8.4 abc	32.4 a-e	38.6 b-j
CT/31-09	8053.5 abc	19.6 abc	7.5	11.8 abc	8.8 a	31.2 def	38.9 b-j
CT/31-15	7285.0 b-e	19.9 ab	7.5	11.7 abc	8.6 abc	31.8 cde	36.4 ij
CT/31-43	7187.5 cde	19.0 bcd	7.7	11.4 a-d	8.4 abc	30.1 ef	37.4 f-j
CT/33-02	7149.0 de	18.9 bcd	7.8	11.4 a-d	8.7 abc	31.1 def	39.0 b-j
CT/33-35	8109.0 ab	18.7 b-e	7.5	11.9 ab	8.7 abc	31.7 c-f	37.0 g-j
CT/33-41	7089.0 e	17.4 d-i	7.6	11.7 abc	8.2 bc	31.4 c-f	39.4 b-j
CT/33-45	7719.0 a-e	18.2 c-g	7.7	11.3 a-d	8.4 abc	32.1 b-e	40.3 a-h
CT/35-01	8234.0 a	21.1 a	7.4	12.2 a	8.8 a	30.2 ef	36.8 hij
CT/46-03	7809.0 a-e	16.0 ij	7.6	11.0 bcd	8.6 abc	28.1 f	35.2 j
CT/48-07	7405.0 a-e	17.1 e-i	7.8	10.5 d	8.3 abc	34.9 abc	40.9 a-f
CT/47745	7983.0 a-d	17.9 d-h	7.6	10.9 bcd	8.7 abc	31.0 ef	38.2 c-j
CT/Macis	7468.0 a-e	16.8 ghi	7.6	10.9 bcd	8.5 abc	30.7 ef	38.4 c-j
CT/Argentario	7229.5 cde	17.6 d-i	7.6	11.3 a-d	8.7 abc	35.8 ab	41.7 a-d
	**	**	ns	*	**	**	**
Control	5639.0	14.8	7.6	10.8	8.4	33.5	41.4
Overall mean	7492.9	17.7	7.6	11.3	8.4	32.4	39.2
Local RS mean	7594.9	17.9	7.6	11.4	8.4	32.2	39.0
Com. RS mean	7348.8	17.2	7.6	11.1	8.6	33.3	40.0

* and ** indicate values significant at 5% and 1%, respectively; ns: not significant. Means not followed by the same letter within a column are significantly different ($P < 0.05$ and $P < 0.01$) according to Duncan's multiple range test.
CT: Crimson Tide, RS: rootstock, Com.: commercial, C*: chroma, *h*°: hue

33-02 had thicker rinds than the plants grafted onto Macis, whereas CT/35-01, CT/31-15, and CT/31-09 each had a thicker rind than CT/Argentario. The rind thickness increased with fruit size but rind thickness did not increase at the same rate as fruit size. The highest increase in fruit size was 46%, whereas the highest increase in rind thickness was 42% when compared to the control. Overall, the mean increase in fruit size was 32% while the overall mean increase in rind was 20%. Flesh firmness was not significantly affected by rootstocks. Total soluble solid content was significantly affected by the rootstock. Graft combinations CT/35-01, CT/09-01, and CT/33-35 had higher TSS contents than the control fruits, while other graft combinations resulted in TSS contents that were similar to those of the control fruits. Although the effect of rootstock on the taste of watermelon fruits was found to be statistically significant, all of the fruit tested by the panelists received high taste scores of >8 out of 9, with the exception of fruits harvested from the CT/20-02 combination, which had lower taste scores than the other combinations. The flesh color saturation, the chroma value (C*), was significantly affected by rootstocks. A lower C* value was recorded in fruit obtained from the plant grafted onto 46-03 compared to the control fruits. C* values of fruits from other graft combinations were similar to those of the control fruits. The effect of rootstock on the hue angle (h°) of the fruit's flesh color was found to be significant. Fruits from the CT/31-15, CT/31-43, CT/33-35, CT/35-01, and CT/46-03 graft combinations had lower h° values compared to control fruits. Other graft combinations resulted in h° values that were similar to those of the control fruits. Flesh colors of fruits were observed to be bright red and orange-red. It was observed that as the maturity level of the fruit progressed, the flesh color changed from bright red (lower h°) to orange-red (higher h°).

Discussion

In this study, sufficient graft compatibility between watermelon and the bottle gourd genotypes used were determined (Table 1), as reported in previous studies (Yetişir et al. 2007). The partial low survival rate in local bottle gourds when compared to the commercial rootstocks can be attributed to low homogeneity in the seedling characteristics (hypocotyl diameter and length) of local bottle gourds. Since rootstocks and scions of vegetables contain a high level of water, abiotic factors such as temperature, humidity, and light intensity have a critical effect on survival rates. As these parameters approach optimum levels, the survival rate of the grafted plant increases. In agreement with our results, it has been reported that there is no compatibility problem between bottle gourd and watermelon and, under appropriate conditions in a postgraft care unit, sufficient (100%) survival rates can be achieved (Oda 1995; Yetişir 2001; Yetişir et al. 2007).

The plant growth parameters examined in this study were significantly enhanced by rootstocks in comparison to the ungrafted control plants. It was found that some of the rootstocks used in the study were more vigorous than the CT watermelon cultivar. Among the grafted plants, there were also significant differences in the main stem length, leaf number, leaf area, and shoot and root dry weight. All of the local bottle gourd landraces had significantly higher leaf numbers than the controls, whereas the plants grafted onto 01-17, 07-04, 31-08, 31-09, 31-15, 33-35, 33-41, 35-01, 33-41, 46-03, and 47745 had higher leaf areas than the control plants. Local bottle gourds showed similar results to the commercial rootstocks with regard to the number of leaves and the leaf area. CT/46-03, CT/01-16, and CT/01-17 showed superior shoot growth performance in comparison to both the commercial rootstocks and the controls, while 13 of the local rootstocks showed similarities with the commercial rootstocks regarding shoot growth. Fourteen graft combinations with local rootstocks and Argentario produced higher root dry weights than the control plants, while others showed similar root growth performance (Table 1). Our results are in agreement with previous studies that showed that vegetative growth was promoted by *Lagenaria* rootstocks (Yetisir and Sari 2003; Colla et al. 2008; Prioetti et al. 2008). The final fruit size, yield, and quality parameters of a variety are obviously influenced by the scion and environmental factors, but the rootstock may also have significant effects on plant growth and fruit quality parameters (Davis et al. 2008). The rootstocks of *Lagenaria* and Cucurbitaceae were resistant to *Fon* and watermelon grafted onto these rootstocks showed superior plant growth performance, including root and shoot fresh and dry weights, as compared to the ungrafted control plants (Yetisir and Sari 2003; Boughalleb et al. 2007). Rootstocks with vigorous root systems showed superior tolerance to serious soil-borne diseases such as those caused by *Fusarium* (Yetişir et al. 2003) and *Verticillium* (Bletsos et al. 2003; Lee and Oda 2003).

According to the results of 2 years of investigation, grafting onto local and commercial *Lagenaria* rootstocks caused significant yield increase. Some graft combinations had higher yield parameters (total yield, yield per plant, and marketable yields). This increase can clearly be seen in the yield per plant. The plants grafted onto 6 local bottle gourd genotypes (46-03, 20-06, 01-16, 07-45, 31-09, and 31-15) had higher yields than the plants grafted onto commercial rootstocks. Grafting positively affected the marketable yield, and all of the grafted plants produced higher marketable yields than the control plants. In agreement with our results, yield increase at various levels was determined based on rootstocks and cultivation conditions in previous studies with grafted watermelon (Mondal et al. 1994; Chouka and Jebari 1999; Yetisir and Sari 2003; Miguel et al. 2004; Alan et al. 2007; Alexopoulos et al. 2007; Cushman and Huan 2008; Jifon et al. 2008). In our study, increased fruit size and number resulted in a higher yield in grafted plants, since grafted plants are resistant to soil-borne diseases (data not presented), feature strong root systems, and experience increased photosynthesis due to larger leaf areas.

In this study, as reported in previous studies (Yetişir et al. 2003; Alexopoulos et al. 2007; Prioetti et al. 2008), an increase in fruit weight and rind thickness was determined. However, the increase in rind thickness was not positively correlated with the increase in fruit weight. Fruits from grafted plants and ungrafted plants were found to be similar with regarded to flesh firmness and taste, while CT/35-01, CT/09-01, and CT/33-35 had higher TSS contents than the controls. All grafted plants showed C* values that were similar to that of the controls, except that grafted onto 46-03. Meanwhile, CT/31-15, CT/31-43, CT/33-35, CT/35-01, and CT/46-03 had lower *h*° values compared to the control fruits. In the first year of the experiment, hollow heart was observed in some fruits harvested from grafted plants, but this problem was not observed in the second year of the experiment (data not presented). This result shows that hollow heart is affected not only by rootstocks but also by other environmental and cultural conditions. Cushman and Huan (2008) reported a higher rate of hollow heart incidence in ungrafted watermelon plants than in those that had been grafted. Results of this study are in agreement with previous studies that concluded that bottle gourd rootstocks can be used in watermelon production without significant detrimental effects on fruit quality parameters (Yetisir and Sari 2003; Miguel et al. 2004; Alan et al. 2007).

Yield and external and interior quality characteristics of the watermelon fruits in grafted plants were obviously affected by the scion variety, but rootstock can change these characteristics drastically. 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; Colla et al. 2006). 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.

Abnormalities in the fruit quality of grafted watermelon have been reported, including reduced TSS content, an increased number of yellowish bands in the flesh, insipid taste and flavor, poor texture (more fibers), and decreased firmness (Yamasaki et al. 1994; Lee and Oda 2003). However, positive effects of grafting on watermelon fruit quality, including an increase in fruit weight, flesh firmness, TSS content, and lycopene content (Salam et al. 2002; Davis and Perkins-Veazie 2005), have also been reported. Yetişir et al. (2003) indicated that the quality (fruit weight, TSS content, firmness, rind thickness, and fruit shape) of grafted watermelon was greatly influenced by grafting but that the results varied based on the rootstock used. On the other hand, Miguel et al. (2004) ascertained no significant difference in the TSS content of watermelon fruit from plants grafted onto a *C. maxima* × *C. moschata* hybrid rootstock when compared with controls. Grafting can affect various quality parameters of watermelon. Rootstock/scion combinations should be carefully selected for specific climatic and geographic conditions and cultivation practices. The appropriate selection of rootstocks/scion and growing practices can help control soil-borne diseases and also increase yield and improve fruit quality (Davis et al. 2008).

The majority of Turkish bottle gourd genotypes had sufficient survival rates. The rootstock genotypes promoted plant growth and the grafted plants had higher shoot and root dry weights than the control plants. The plants grafted onto 6 local rootstocks had greater total yields than those grafted onto commercial rootstocks. Among the local bottle gourds landraces, 01-16, 07-45, 20-06, 31-09, 31-15, and 46-03 were found to be promising genotypes with regard to the total yield and quality parameters. The results showed that Turkish *L. siceraria* germplasm has powerful rootstock potential and is a good resource for rootstock breeding programs with regard to the traits investigated. Further research studies need to be conducted to provide comprehensive data addressing the rootstock potential of Turkish *L. siceraria* germplasm in terms of biotic and abiotic stress tolerance.

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