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Performance of ''‘Rio Red'' Grapefruit on Seven Rootstocks in the Eastern Mediterranean Region of Turkey

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ABSTRACT

The effects of rootstocks such as 'sour orange' (*Citrus aurantium* L. var. ‘Yerli’), 'Carrizo' and 'Troyer citranges' (*Citrus sinensis* Osb. x *Poncirus trifoliata* Raf), 'Smooth Flat Seville sour orange' (*Citrus* spp. hybrid of uncertain origin), 'Brazilian sour orange' (*Citrus aurantiam* L. var. ‘Brasilian’), 'Volkameriana' (*Citrus volkameriana* Tan. and Pasq.) and 'Calamondin' (possibly *Citrus reticulate* var. austere×Fortunella hybrid, Swingle) on plant growth, fruit yield, and quality of ‘Rio Red’ grapefruit were investigated from 2008 to 2012. Rootstocks were found to have significant effects on plant growth, fruit yield, and quality. ‘Rio Red’ grapefruit trees budded on 'Carrizo' and 'Troyer citranges' showed higher vegetative growth parameters (canopy height, diameter, and volume) than the trees on the other rootstocks. The trees on 'Volkameriana' and 'Carrizo citrange' produced higher percentage of cumulative yield of about 55.1 and 34.3%, respectively, than the trees on 'sour orange'. ‘Rio Red’ grapefruit budded on 'Carrizo citrange' had higher fruit quality such as thin rind, high juice content, and more color development than the other rootstocks. 'Carrizo citrange' was the most promising rootstock for ‘Rio Red’ grapefruit in Dörtyol, Eastern Mediterranean region of Turkey.

Keywords: Citrus paradisi, Fruit yield, Fruit quality, Plant growth, Rootstocks.

INTRODUCTION

Citrus production of Turkey reached 3,613,770 tons in 2011, with an increase of 45.0% in the last 10 years. The agronomic statistics of 2011 indicated that total citrus production of Turkey is composed of orange, in the first place, (1,730,150 tons), mandarin as the second (872,251 tons), lemon as the third (790,211 tons) and grapefruit as the fourth (218,988 tons). In Turkey, grapefruit production has increased by 75.2% in the past decade (FAO, 2011) and hence it has high export opportunity, good yield of tree, adaptation for ecological conditions and positive effect on human health.

The major red-flesh grapefruit varieties in Turkey are ‘Star Ruby’ and ‘Rio Red’. ‘Rio Red’ is the latest variety and was derived from ‘Redblush’ by bud irradiation. It was discovered by R. A. Hensz in 1976. The general appearance of ‘Rio Red’ fruit is quite attractive. The fruits are sometimes pear-shaped or elongated, especially in dry areas. The skin is slightly thick with numerous deep red zones. The internal coloring is a little less marked than that of ‘Star Ruby’. Color intensity may be uneven at the beginning and end of the season. The juice content is exceptional and the flesh is particularly supple. Only one to three seeds are found in each fruit (Saunt, 2000).

With changes in customer preferences, many new citrus cultivars have been

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introduced to Turkey. Hence, it is valuable to know the favorable ecological conditions for the cultivars chosen. Further, factors like cultivar characteristics, rootstocks employed, growing conditions along with cultural managements, type of flowers, and the fruit drops can affect citrus cultivars yield and quality performance (Demirkeser *et al*., 2009).

Rootstocks may influence citrus growth and development, including yield, fruit quality, and tolerance to stress caused by biotic and abiotic factors (Filho *et al*., 2007). While 'trifoliate orange', 'Troyer' and 'Carrizo citranges' are also used, the main rootstock of Turkish citrus production is 'sour orange'. 'Sour orange' has been the most desirable citrus rootstock in the world because of its adaptability to a range of soil conditions and excellent fruit quality induced. However, the appearance of *Citrus tristeza virus* in the Mediterranean region (Kyriakou and Polykarpou, 1989) has necessitated a research program to replace 'sour orange' with rootstocks tolerant to tristeza for almost all the commercial cultivars (Tuzcu *et al*., 1998; Kaplankiran *et al*., 2005; Demirkeser *et al*., 2009). The use of 'Carrizo citrange' has been increased lately, especially in the Eastern Mediterranean region of Turkey (Kaplankiran *et al*., 2001).

The majority of the research on grapefruit has been directed to rootstocks, instead of cultivars. This is the result of the importance in finding an alternative rootstock for sour orange due to the susceptibility of sour orange to *Citrus tristeza virus* (CTV). Considerable data has been collected on the culture of common grapefruit cultivars such as 'Marsh Seedless' (Economides and Gregoriou, 1993; Mehrotra *et al*., 1999; Stuchi *et al*., 2002; Acikalin *et al*., 2008) and 'Redblush' (Fallahi, 1992; Tuzcu *et al*., 1994; Tuzcu and Toplu, 1999; Ramin and Alirezanezhad, 2005) used in the rootstock trials throughout different grapefruit growing regions worldwide.

The objective of this study was to determine the plant growth, fruit yield, and quality characteristics of 'Rio Red' grapefruit budded on seven rootstocks in the Dörtyol, Eastern Mediterranean region of Turkey.

MATERIALS AND METHODS

Plant Material and Field Trial

'Rio Red' grapefruit variety was budded on the rootstocks 'sour orange' (*Citrus aurantium* L. var. 'Yerli'), 'Carrizo' and 'Troyer citranges' (*Citrus sinensis* Osb.×*Poncirus trifoliata* Raf), 'Smooth Flat Seville sour orange' (*Citrus* spp. hybrid of uncertain origin), 'Brazilian sour orange' (*Citrus aurantiam* L. var. 'Brasilian'), 'Volkameriana' (*Citrus volkameriana* Tan. and Pasq.) and 'Calamondin' (possibly *Citrus reticulate* var. austere×Fortunella hybrid, Swingle). The experimental design was completely randomized with four replications and a single tree per plot. The budded trees were planted in 2005 with 7×6 m spacing at the Research Station of Mustafa Kemal University, Agricultural Faculty, Citrus Experimental Station, Dörtyol (36^{o}-09' E; 36^{o}-51' N; 9 m altitude).

The soil texture of the plot located in Dörtyol (Hatay) was sandy-silt. The soil was coarse textured (17.6% coarse sand, 37.6% fine sand, 23.8% silt, 22% clay) and slightly alkaline to alkaline in the soil profile (pH 7.80, 7.98, and 8.25 for 0–30, 30–60 and 60–90 cm depth, respectively, in 1:2.5 soil:water suspension), rich in carbonate content (61–63 g kg^{-1} for 0–60 cm and 113.5 g kg^{-1} for 60–90 cm depth). The area has a Mediterranean climate with an annual mean temperature of 19.1ºC and an annual mean rainfall of 950 mm. The trees were irrigated weekly from May to October using drip irrigation. In 2012, the trees were fertilized with 500 g nitrogen (N) tree^{-1} (2/3 of it at the end of February and 1/3 at the end of May), 300 g phosphorus (P) tree^{-1} (in December) and 300 g potassium (K) tree^{-1} (by the end of January). Disease and pest

populations were controlled according to integrated pest management (IPM) method.

Fruit Yield and Quality, and Growth Measurements

Each year, fruit yield of each tree was determined during harvesting. Fruits were harvested and weighed at harvest time (at the end of December or at the beginning of January). Each year, random samples of 15 fruits from each tree were collected for fruit quality analysis. The fruit samples were weighed, and fruit diameter at the equator was measured with a digital caliper and also rind thickness was measured after cutting in half with a digital caliper (Milutoyo CD-15CPX). The fruits were weighed and juiced using a standard juicer; then, juice was weighed, and expressed as a percentage of the total fruit weight. Total soluble solids (TSS) content was determined with a refractometer (Atago ATC-1E model) using a few drops of juice. The total acidity (TA) was determined by titration of 5 ml of fruit juice with 0.1 N sodium hydroxide (NaOH) to pH 8.1, and it was expressed as g citric acid 100 ml^{-1} juice. Fruit rind color was determined with a Minolta Chroma Meter CR-300 (Osaka, Japan). Color measurements were recorded using the CIE *L*a*b** color space. From these values, hue angle was calculated as $h^o = tan\ -1(b^*/a^*)$. Color values for each fruit were computed as means of two measurements taken from opposite sides at the equatorial region of the fruit.

In January (2011 and 2012), canopy height and canopy diameter in the two tree directions were measured after harvesting to obtain the mean diameter. The canopy volume (CV) was calculated from canopy height and spread, considering canopy as a prolate spheroid and applying the formula: $CV = 4/3\pi ab^2$, where *a* is the major axis length/2, and *b* is the minor axis length/2 (Westwood, 1993). In addition, stock and scion trunk circumferences were measured 10 cm below and above the bud union and their scion/stock ratio was calculated. The scion trunk circumferences were converted to trunk cross-sectional area (TCSA). The yield efficiency was estimated as the ratio of yield to canopy volume (kg/m^3) for each rootstock in the 7^{th} year after planting (YAP).

Experimental Design and Data Analysis

A completely randomized design with four replications was used. The data recorded in all the seasons were subjected to ANOVA using SAS program (SAS, 2005) and means were compared with Tukey test at 5% level of significance.

RESULTS AND DISCUSSION

Vegetative Growth

The rootstock significantly affected canopy height, diameter and volume, and trunk cross-sectional area (TCSA), but not scion to stock ratio of ‘Rio Red’ grapefruit trees in the 7^{th} year after planting (YAP) (Table 1). The trees of ‘Rio Red’ grapefruit budded on 'Carrizo citrange' were higher than those on other studied rootstocks. The shorter trees were those on 'Calamondin', followed by 'Volkameriana' and 'Brazilian sour orange', and did not significantly differ from each other. These results disagreed with the findings of Stover *et. al*. (2004), who reported that trees of ‘Oroblanco’ and ‘Melogold’ grapefruit hybrids on 'Carrizo citrange', which performed poorly on calcareous soils, were shorter than those on 'Smooth Flat Seville' and 'Volkameriana'. In addition, trees on 'Troyer citrange' in ‘Marsh Seedless’ grapefruit had higher vegetative growth parameters than trees on the other rootstocks tested (Stuchi *et al*., 2002).

The trees budded onto 'Carrizo' and 'Troyer citranges' had the highest canopy diameter and volume (Table 1). The canopy diameter and volume of ‘Rio Red’ trees on 'Brazilian sour orange' was the smallest

Table 1. The effects of different rootstocks on some vegetative characteristics of 'Rio Red' grapefruit (in the 7th YAP[b]).

Rootstocks	Canopy height (m)	Canopy diameter (m)	Canopy volume (CV) (m^3)	Trunk cross-sectional area (TCSA) (cm^2)	Scion/Stock ratio
Sour orange	2.71 a-c	2.67 cd	10.23 bc	100.88 c	0.92
Carrizo citrange	2.96 a	3.20 a	15.44 a	151.38 a	0.87
Troyer citrange	2.77 ab	3.24 a	14.40 a	145.06 a	0.85
Smooth Flat Seville	2.78 ab	2.67 cd	10.60 bc	110.01 b	0.88
Brazilian sour orange	2.65 bc	2.43 d	8.63 c	103.62 bc	0.90
Volkameriana	2.60 bc	2.78 bc	10.18 bc	110.89 b	0.84
Calamondin	2.48 c	3.09 ab	11.32 b	100.18 c	0.90
HSD (5%)	0.25	0.31	2.54	8.98	NS[a]
Mean	2.71	2.87	11.54	117.43	0.88

[a] NS: Non-Significant. [b] year after planting

among the rootstocks tested. These results are in agreement with the findings of Chohan *et al*. (1988) and Mehrotra *et al*. (1999), who reported that trees of 'Marsh Seedless' grapefruit on 'Carrizo' and 'Troyer citranges' had higher vegetative growth parameters than those on the other rootstocks. In addition, the highest canopy volume was determined on 'Troyer citrange' in 'Marsh' and 'Davis' grapefruits (Bevington and Cullis, 1990), on 'Volkameriana' and 'Carrizo citrange' in 'Redblush' grapefruit (Fallahi, 1992), on 'sour orange' in 'Frost Marsh Seedless' (Economides and Gregoriou, 1993) and 'Marsh Seedless' grapefruits (Acikalin *et al*., 2008), on 'Volkamerina' in 'Melogold' grapefruit hybrid (Stover *et al*., 2004). The growth and development of plants were affected by various factors, such as, rootstock, genotype, ecological conditions, cultivation techniques etc. (Georgiou and Gregoriou, 1999).

The TCSA of trees on 'Carrizo' and 'Troyer citranges' were significantly higher than those on the remaining rootstocks, while those on 'Calamondin' showed the lowest value, followed by 'sour orange' and 'Brazilian sour orange' (Table 1). These findings are in harmony with those of Chohan *et al*. (1988) on 'Marsh Seedless' grapefruit, who found that the highest TCSA was with 'Carrizo citrange', followed by 'Troyer citrange'. However, the highest TCSA was found on 'sour orange' in 'Star Ruby' (Seker, 1995), 'Rio Red' and 'Henderson' (Temiz and Kaplankiran, 2007), and 'Marsh Seedless' (Acikalin *et al*., 2008), on 'Troyer citrange' in 'Marsh Seedless' (Stuchi *et al*., 2002), on 'Volkameriana' in 'Oroblanco' and 'Melogold' (Stover *et. al*., 2004), on 'sour orange' and 'Volkameriana' in 'Marsh Seedless' and 'Redblush' grapefruits (Ramin and Alirezanezhad, 2005). On the other hand, Tuzcu *et al*. (1994) concluded that TCSA of 'Redblush' grapefruit trees was not affected by the rootstocks.

The ratio between scion and rootstock trunk girth is used as a scion/rootstock affinity indicator, whereas values close to 1 are associated with very good affinity (Bisio *et al*., 2003). Rootstock does not have a significant effect on the scion to stock ratio, however, the highest affinity was found with 'sour orange' (0.92) and the lowest affinity was found with 'Volkameriana' (0.84), followed by 'Troyer' and 'Carrizo citranges' (0.85 and 0.87, respectively) (Table 1). Similar results were reported by Tuzcu *et al*. (1994) on 'Redblush' grapefruit, who stated that 'sour orange' induced the higher scion/stock girth ratio as compared with 'Carrizo' and 'Troyer citranges'. In addition, similar results were also obtained in the other citrus species by Georgiou and Gregoriou (1999), Hassan *et al*. (2000), Georgiou (2002), Bassal (2009), Yildirim *et*

al. (2010) and Yildiz *et al*. (2012), who mentioned that the highest scion/stock trunk girth ratio was on 'sour orange'.

Fruit Yield

The yield was significantly affected by the rootstocks in 'Rio Red' grapefruit, except for the 3rd YAP (Table 2). The highest yield was obtained from the trees on 'Volkameriana' and 'Troyer citrange' in the 4th and 5th YAP, and 'Volkameriana' and 'Carrizo citrange' in the 6th YAP. In the 7th YAP, the highest yield trees were those on 'Carrizo citrange', whereas 'Smooth Flat Seville' was the lowest. Becerra-Rodríquez *et al*. (2008) reported in Mexico that the mean yield for 7- to 10-year-old 'Rio Red' cultivar budded on sour orange was found to be about 147 kg tree^{-1}. Like many other horticultural fruit species, the fruit yield is dependent upon species, cultivar, rootstock, tree age as well as ecological conditions (Tuzcu *et al*., 1994; Kaplankiran *et al*., 2005).

The rootstocks significantly affected cumulative yield (Table 2). The highest cumulative yield of 'Rio Red' grapefruit based on five-year period was obtained from the trees on 'Volkameriana', followed by 'Carrizo citrange'. Trees on 'Brazilian sour orange', 'Smooth Flat Seville' and 'sour orange' had the lowest cumulative yield. The trees on 'Volkameriana' and 'Carrizo citrange' produced higher percentage of cumulative yield by about 55.1 and 34.3%, respectively, than trees on 'sour orange', which is the current rootstock used in Turkey. These results are in agreement with those of the previous studies, where the 'Redblush' (Fallahi, 1992; Yalcin and Hizal, 1994) and 'Marsh Seedless' (Tuzcu and Toplu, 1999) trees on 'Carrizo citrange' and 'Volkameriana' were more productive than those on 'sour orange'. In addition, Chohan *et al*. (1988) and Mehrotra *et al*. (1999) indicated the positive effect of 'Carrizo citrange' on the yield of 'Marsh Seedless', whereas Ramin and Alirezanezhad (2005) reported that on 'Marsh Seedless' and 'Redblush' grapefruits, the highest yielding rootstock was 'Volkameriana'. The results obtained regarding 'sour orange' productivity are in agreement with Louzada *et al*. (2008), who reported that the lowest yield of 'Rio Red' trees were on 'sour orange', except for Goutou sour orange. On the other hand, Tuzcu *et al*. (1994) mentioned that fruit yield of 'Redblush' grapefruit trees was not affected by the rootstock.

To indicate the effectiveness of the rootstock on productivity of trees in relation to tree size, the yield per canopy volume was calculated. Effects of rootstocks on yield efficiency (kg/m^3) were found to be

Table 2. Annual and cumulative yield and yield efficiency (in the 7th YAP) of 'Rio Red' grapefruit on different rootstocks.

Rootstocks	Yield (kg per tree) (YAP) [b]						Yield to canopy volume (kg m^{-3})
	3th	4th	5th	6th	7th	Cumulative yield	
Sour orange	2.42	7.96 c	17.40 c	43.04 c	72.61 ab	143.42 c	7.19 ab
Carrizo citrange	3.60	12.55 b	27.55 bc	61.60 ab	79.28 a	184.58 ab	5.23 c
Troyer citrange	2.20	19.95 a	31.06 ab	23.97 d	73.41 ab	150.60 bc	5.17 c
Smooth Flat Seville	2.64	3.52 d	22.93 bc	56.89 bc	56.88 b	142.85 c	5.36 c
Brazilian sour orange	2.31	6.78 cd	16.15 c	50.06 bc	63.22 ab	138.51 c	7.45 a
Volkameriana	6.34	20.18 a	40.02 a	72.55 a	74.07 ab	213.17 a	7.31 ab
Calamondin	4.78	4.03 cd	23.41 bc	51.46 bc	73.00 ab	156.67 bc	6.46 b
HSD (5%)	NS[a]	4.22	11.84	14.84	19.96	34.82	0.97
Mean	3.47	10.71	25.50	51.37	70.35	161.40	6.31

[a] NS: Non-Significant. [b] year after planting

statistically significant (Table 2). The yield efficiency was the highest on 'Brazilian sour orange', followed by 'Volkameriana' and 'sour orange'; and the lowest for 'Troyer' and 'Carrizo citranges', and 'Smooth Flat Seville'. 'Sour orange' induced high yield efficiency for 'Rio Red' grapefruit in Turkey (Temiz and Kaplankiran, 2007) compared to 'Carrizo' and 'Troyer citranges', whereas the 'Marsh Seedless' trees on 'Carrizo citrange' produced higher yield efficiency than those on 'sour orange' and 'Troyer citrange' (Tuzcu *et al*., 1994). On the contrary, Seker (1995), reported that on 'Star Ruby' grapefruit, the lowest yield efficiency was on 'sour orange'. On the other hand, Tuzcu and Toplu (1999) concluded that yield efficiency of 'Redblush' grapefruit trees was not affected by the rootstocks. Our results showed that there was no relationship between the mean canopy volume and the fruit yield per tree. Therefore, the yield efficiency was the highest for the rootstocks that had low tree size.

Fruit Quality

The rootstocks had different effects on fruit weight and diameter, and rind thickness in the 6th YAP, but not in the 7th YAP (Table 3). In the 6th YAP, the fruits from trees on 'Volkameriana' and 'sour orange' were the heaviest; while the lightest fruits were obtained from the trees on 'Calamondin', followed by 'Smooth Flat Seville'. Although the fruit weight was not significantly affected by rootstocks in the 7th YAP, the trees on 'Brazilian sour orange' gave the heaviest fruits. Generally, the fruit weight of 'Rio Red' grapefruit in the 6th YAP were higher than those of the 7th YAP, which was about two-fold more number of fruits per tree. A negative relationship between the number of fruits and the size of fruits is often confirmed in citrus. Tuzcu *et al*. (1994) on 'Redblush' and Tuzcu and Toplu (1999) and Acikalin *et al*. (2008) on 'Marsh Seedless' grapefruits reported that trees on 'sour orange', 'Carrizo' and 'Troyer citranges' produced similar fruits in weight and size. However, the highest fruit weight was found on 'Carrizo' and 'Troyer citranges' in 'Redblush' (Fallahi *et al*., 1989) and 'Marsh Seedless' (Mehrotra *et al*., 1999), on 'Palestine sweet lime', 'rough lemon' and 'Volkameriana' in 'Frosh Marsh Seedless' (Economides and Gregoriou, 1993), on 'sour orange', 'Carrizo' and 'Troyer citranges' in 'Marsh Seedless' and 'Redblush' grapefruits (Yalcin and Hizal, 1994), and on 'Goutou' in 'Oroblanco' grapefruit hybrid (Stover *et al*., 2004). Lederman *et al*. (2005) in Brazil and Becerra-Rodríguez *et al*. (2008) in Mexico reported that the fruit weight of 'Rio Red' grapefruit on 'Rangpur lime' and 'sour orange' was 296.9 g and 522.3 g,

Table 3. Effects of rootstocks on the fruit weight, fruit diameter and rind tickness of the 'Rio Red' grapefruit.

Rootstocks	Fruit weight (g)		Fruit diameter (mm)		Rind thickness (mm)	
	6th YAP[b]	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP
Sour orange	524.93 a	324.80	109.38 a	93.85	10.08 bc	9.69
Carrizo citrange	498.01 ab	325.42	106.03 ab	92.33	9.84 bc	8.94
Troyer citrange	510.83 ab	338.71	106.79 ab	93.11	10.84 ab	9.25
Smooth Flat Seville	459.20 bc	326.92	103.81 b	92.74	9.42 c	9.14
Brazilian sour orange	481.43 a-c	360.35	105.77 ab	97.19	9.80 bc	9.08
Volkameriana	532.57 a	314.53	110.20 a	93.63	11.34 a	9.45
Calamondin	436.07 c	318.64	103.02 b	93.12	9.08 c	8.27
HSD (5%)	53.91	NS[a]	4.81	NS	1.12	NS
Mean	491.86	329.91	106.43	93.71	10.06	9.12

[a] NS: Non-Significant. [b] year after planting

respectively. The differences in the mean fruit weight for a given cultivar are probably attributable to rootstock, climatic, and management factors in the studies.

The highest fruit diameter and the thickest fruit rind were shown by fruits from the trees on 'Volkameriana', followed by 'sour orange' (Table 3). The lowest values were found on 'Calamondin' and 'Smooth Flat Seville'. Similar results on fruit diameter and rind thickness of 'Marsh Seedless' and 'Redblush' grapefruit varieties were obtained by Ramin and Alirezanezhad (2005) with the highest values in fruits collected from trees on 'Volkameriana', but trees on 'sour orange', 'Carrizo' and 'Troyer citranges' produced similar values in this parameters. Tuzcu *et al*. (1994) also reported that rind thickness of 'Redblush' grapefruit was not influenced by the rootstocks.

The juice content was significantly affected by rootstocks in both seasons (Table 4). The fruits from trees budded on 'Carrizo citrange' in the 6th YAP and 'Brazilian sour orange' in the 7th YAP had the highest juice content as compared to those bearing on the other rootstocks; although those on 'Volkameriana' (in the 6th YAP) and 'Calamondin' (in the 7th YAP) showed the lowest value. As per the mean juice content values of the two years, 'Carrizo citrange', 'sour orange' and 'Brazilian sour orange' was higher than those on the remaining rootstocks, while those on 'Calamondin' and 'Volkameriana' showed the lowest value. Ramin and Alirezanezhad (2005) mentioned that, on 'Marsh Seedless' and 'Redblush' grapefruit varieties, the highest juice content had fruits on 'sour orange', while the lowest value was found with 'Volkameriana'. In contrary, sour orange decreased the juice content for 'Redblush' (Tuzcu *et al*., 1994) and 'Marsh Seedless' (Acikalin *et al*., 2008). However, Tuzcu and Toplu (1999) on 'Marsh Seedless' and 'Redblush' grapefruits and Stover *et al*. (2004) on 'Melegold' grapefruit hybrid found that the effect of the rootstocks on the juice content was insignificant. The juice content of 'Rio Red' grapefruit on 'Rangpur lime' in Brazil (Lederman *et al*., 2005), 'Carrizo citrange' in Turkey (Temiz and Kaplankiran, 2007), and 'sour orange' in Mexico (Becerra-Rodríguez *et al*., 2008) were 41.7, 39.1, and 47.8%, respectively. In addition, Louzada *et al*. (2008) reported that fruits of 'Rio Red' grapefruit on 7 rootstocks had a juice content between 48.0 and 49.5%. The juice content was changed according to the used rootstock, different ecological conditions, and management factors.

The highest percentage of total acids (TA) was in fruits from trees on 'Brazilian sour orange', followed by 'sour orange', whereas the lowest TA was detected in fruits from trees on 'Calamondin' and 'Volkameriana' in both seasons (Table 4). Temiz and Kaplankiran (2007) on 'Rio

Table 4. Effects of rootstocks on the juice content, total acids (TA), total soluble solids (TSS), TSS/TA ratio of the 'Rio Red' grapefruit.

Rootstocks	Juice content (%)		Total acids (TA) (%)		Total soluble solids (TSS) (%)		TSS/TA ratio	
	6th YAP [a]	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP
Sour orange	42.84 ab	45.23 ab	1.63 a	1.64 a	8.45 ab	8.83 a	5.18 bc	5.38 b
Carrizo citr.	44.26 a	44.45 ab	1.59 ab	1.55 ab	8.10 ab	8.20 ab	5.09 c	5.29 b
Troyer citr.	41.37 a-c	44.47 ab	1.61 a	1.57 ab	8.27 ab	8.40 ab	5.14 c	5.35 b
Smooth F.Sev.	42.00 ab	42.59 bc	1.58 ab	1.58 ab	9.00 a	8.90 a	5.70 ab	5.63 ab
B.sour orange	41.25 bc	47.29 a	1.64 a	1.64 a	8.85 ab	8.50 ab	5.40 a-c	5.18 b
Volkameriana	39.08 c	44.86 ab	1.49 b	1.49 b	7.45 b	7.45 b	5.00 c	5.00 b
Calamondin	42.92 ab	39.68 c	1.49 b	1.47 b	8.80 ab	9.00 a	5.91 a	6.12 a
HSD (5%)	2.90	3.25	0.11	0.15	1.40	1.10	0.53	0.71
Mean	41.96	44.07	1.58	1.56	8.42	8.47	5.34	5.42

[a] year after planting

Red' grapefruit found that the fruits from trees budded on 'sour orange' gave TA significantly higher than those on 'Carrizo citrange'. However, Lederman *et al*. (2005) reported that the TA of 'Rio Red' grapefruit on 'Rangpur lime' in Brazil was 1.58%. However, no differences were determined in the TA of 'Frost Marsh Seedless' (Ecomides and Gregoriou, 1993), 'Marsh Seedless' and 'Redblush' (Tuzcu and Toplu, 1999; Ramin and Alirezanezhad, 2005) and 'Marsh Seedless' grapefruit varieties (Acikalin *et al*., 2008) budded on different rootstocks.

The rootstocks significantly affected total soluble solids (TSS) in both seasons (Table 4). 'Rio Red' fruits from trees on 'Smooth Flat Seville', 'Calamondin', 'Brazilian sour orange' and 'sour orange' had higher TSS than the other rootstocks, whereas the lowest TSS was obtained on 'Volkameriana' in both seasons. These results are in agreement with those of the previous studies, where the trees on 'Volkameriana' had the least TSS (Stuchi *et al*., 2002; Stover *et al*., 2004; Ramin and Alirezanezhad, 2005). Similar results were also found for 'Rio Red' budded on 7 rootstocks by Louzada *et al*. (2008), reporting that sour orange was higher than those on the remaining rootstocks, and fruits had TSS between 9.5 and 10.5%. However, these results showed that TSS of 'Rio Red' grapefruit registered lower content than the findings (9.3 and 10.7%, respectively) of Lederman *et al*. (2005) and Temiz and Kaplankiran (2007), who indicated that TSS was negatively correlated with temperature.

The TSS/TA ratio was affected by the rootstocks in both seasons (Table 4). It was higher in fruits of trees budded on 'Calamondin' than those on the other rootstocks tested, whereas the lowest TSS/TA ratio was recorded for trees budded on 'Volkameriana' in both seasons. Our TSS/TA ratio of 'Rio Red' grapefruit results obtained in this study was lower than those of 'Rio Red' grapefruit by Lederman *et al*. (2005), and Temiz and Kaplankiran (2007), who reported that fruits on 'Rangpur lime' and 'Carrizo citrange' rootstocks had TSS/TA ratio of 5.88 and 6.08, respectively. On the other hand, the TSS/TA ratio in fruits of 'Marsh Seedless' and 'Redblush' (Tuzcu and Toplu, 1999), 'Marsh Seedless' (Acikalin *et al*., 2008) and 'Rio Red' grapefruit (Louzada *et al*., 2008) were not influenced by the rootstocks.

The rootstocks significantly affected fruits rind color values (Table 5), except for *L** value. In the 6th and 7th YAP, the *L** value (a measure of the brightness of the color) of 'Rio Red' fruits ranged from 68.07 ('Troyer citrange') to 70.35 ('Brazilian sour orange'); and from 68.98 ('Volkameriana') to 73.19 ('Troyer citrange'), respectively. The highest croma value was shown by fruits from trees on

Table 5. Effects of rootstocks on the fruit rind colour of the 'Rio Red' grapefruit.

Rootstocks	*L**		Croma		Hue angle	
	6th YAP [b]	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP
Sour orange	69.86	69.51	48.53 ab	50.98 a-c	72.08 ab	72.76 bc
Carrizo citrange	68.41	72.59	46.64 b	50.70 bc	67.52 c	70.52 c
Troyer citrange	68.07	73.19	48.02 ab	53.00 a-c	68.28 bc	75.58 ab
Smooth Flat Seville	68.72	69.13	47.41 b	49.80 c	69.24 a-c	74.20 a-c
Brazilian sour orange	70.35	71.07	49.88 a	54.64 a	72.02 ab	76.85 ab
Volkameriana	69.16	68.98	48.15 ab	52.23 a-c	73.45 a	77.74 a
Calamondin	70.21	71.22	48.72 ab	53.80 ab	71.33 a-c	76.59 ab
HSD (5%)	NS[a]	NS	2.20	3.70	4.21	4.80
Mean	69.25	70.81	48.19	52.16	70.56	74.89

[a] NS: Non-Significant, [b] year after planting

'Brazilian sour orange' in both seasons, and the lowest one was detected in fruits from trees on 'Carrizo citrange' and 'Smooth Flat Seville' in the 6th and 'Smooth Flat Seville' in the 7th YAP. Significant differences were found among studied rootstocks in terms of the hue angle values, and 'Rio Red' grapefruit fruits from trees budded on 'Carrizo citrange' had the lowest hue angle value (more color development) in both seasons. The fruits from trees on 'Volkameriana' in both seasons had the lowest rind color as compared with the other rootstocks. Similar results on fruits with good color of 'Washington Navel' and 'Shamouti" oranges were obtained by Tuzcu *et al*. (1999), while the best color was observed in fruits collected from trees on citrange rootstocks. García–Sánchez *et al*. (2006) and Bassal (2009) reported that trees of 'Clemenules' and 'Marisol' clementines on 'Carrizo citrange' produced fruits with more colour development than those on the other rootstocks. In the contrary, Ali (2002) on 'Fremont' reported that the best rind color was on 'sour orange' in comparison with those on 'Carrizo citrange'. The fruit coloration may chang according to the used rootstock, climatic conditions (illumination, temperature differences between day and night, etc.) and cultural practices (pruning, irrigation, fertilization, etc.).

CONCLUSIONS

In Turkey, all citrus cultivars are mainly budded on 'sour orange' that are highly susceptible to *Citrus tristeza virus*. Therefore, 'sour orange' rootstock has to be replaced with more resistant varieties. In this study, seven different rootstocks were tested and the tree size, yield, and fruit quality of 'Rio Red' grapefruit were influenced by the rootstocks. 'Brazilian sour orange' and 'Volkameriana' rootstocks achieved the highest yield efficiency. However, trees on 'Volkameriana' and 'Carrizo citrange' had the highest cumulative yield. 'Rio Red' grapefruit budded on 'Carrizo citrange' had higher fruit qualities such as thin rind, high juice content, and more color development than the other rootstocks, and the fruits with low fruit quality were obtained on 'Volkameriana'. The results showed that 'Carrizo citrange' was very promising as an alternative rootstock.

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عملکرد و کیفیت گریپ فروت ''رد ریو'' روی هفت پایه مختلف در منطقه مدیترانه-ای شرق ترکیه

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چکیده

در این پژوهش، اثر هفت پایه مرکبات شامل نارنج (*Citrus aurantium* L. var. 'Yerli')، 'Troyer citranges' (*Citrus sinensis* Osb. x *Poncirus trifoliata* و 'Carrizo' Raf)، ونارنج صاف و نرم سیویل(گونه ای از مرکبات هیبرید با منشا نا معلوم)، نارنج برزیلی (*Citrus aurantiam* L. var. 'Brasilian') و'Volkameriana' ولکا مریانا (*Citrus volkameriana* Tan. and Pasq.) و 'Calamondin' (احتمالا *Citrus reticulate* var.) هیبریدSwingle (austere x Fortunella) روی رشد درخت، عملکرد میوه، و کیفیت گریپ فروت ''رد ریو'' بررسی شد. چنین آشکار شد که پایه ها اثر معنی داری روی رشد، عملکرد و کیفیت میوه داشتند. گریپ فروت ''رد ریو'' پیوند زده روی'Carrizo' and 'Troyer citranges' در مقایسه با پایه های دیگررشد سبزینه ای بیشتری (از نظر ارتفاع ، قطر و حجم پوششی درختان) نشان داد.

درختان پیوند زده روی پایه های ولکا مریانا **و**'Carrizo citrange' در صد عملکرد کل بیشتری (به ترتیب ۵۵.۱٪ و۳۴.۳٪)نسبت به پایه نارنج داشتند. میوه گریپ فروت "رد ریو" پیوند زده روی'Carrizo' citranges' از نظر پوست بیرونی نازکتر، آب بیشتر، و رنگ کامل تر کیفیت میوه بهتری از دیگر پایه ها داشت. در این پژوهش، پایه 'Carrizo citrange' امید بخش ترین پایه برای گریپ فروت "رد ریو" درDörtyol واقع در منطقه شرقی و مدیترانه ای ترکیه بود.