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Growth, yield, and fruit quality of 'Rhode Red Valencia' and 'Valencia Late' sweet oranges grown on three rootstocks in eastern Mediterranean

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The plant growth, yield, yield efficiency, and fruit quality of 'Rhode Red Valencia' and 'Valencia Late' sweet oranges (*Citrus sinensis* (L.) Osbeck) on three rootstocks were evaluated under Eastern Mediterranean climatic conditions of Dörtyol-Hatay, which is one of the oldest and largest citrus and mandarin (*Citrus reticulata* Blanco) production regions in Turkey. The fruit yield was affected by rootstock in both scion cultivars from 2007 through 2010. Trees on 'Troyer' citrange had lower yield than those budded on the other rootstocks. The yield of 'Rhode Red Valencia' and 'Valencia Late' orange trees on 'Carrizo' citrange were about 9% and 19% more than those on 'Troyer' citrange, respectively. But trees on 'Troyer' citrange had significant higher yield efficiency than trees on sour orange and 'Carrizo' citrange, because of canopy volume of 'Troyer' citrange was lower than the other rootstocks. The heaviest fruits of 'Valencia Late' orange trees were harvested from 'Carrizo' citrange (214.69 g), while 'Rhode Red Valencia' orange trees did not show differences regarding the rootstock. The rootstocks had no significant effects on juice content of 'Rhode Red Valencia' and 'Valencia Late' oranges. The effects of the rootstocks in both scion cultivars on juice content, total acids (TA), Brix:TA ratio, and number of seeds per fruit were found to be insignificant.

Key words: Orange, rootstock, fruit quality, plant characteristics, yield.

INTRODUCTION

Turkey's citrus production has reached to approximately 3 600 000 t in 2010; with an increase of 44.2% in the past decade. The statistics of 2010 indicated that among the Turkey's total citrus production, orange is the first (1 710 500 t) species (FAOSTAT, 2010).

The 'Valencia Late' orange (*Citrus sinensis* (L.) Osbeck) is one of the sweet oranges used for juice extraction. It is a late-season fruit, and therefore a popular variety when the navel oranges are out of season. The popularity of 'Valencia Late' juice has been stimulated by the market success of the not-from-concentrate (NFC) pasteurized product. Juice color of the 'Valencia' clone means less juice needed for blending to attain the desired color. 'Rhode Red Valencia' is a clone that has been selected for its high juice color score (Rouse, 2000).

Due to the changes in customer preferences and demands, many new citrus cultivars have been introduced in Turkey. It is not expected that the introduced cultivars will perform similarly in various regions of Turkey where different ecological conditions exist. The different ecological condition effects on citrus productions are apparent. Hence, it is valuable to know the favorable ecological conditions for the cultivars chosen and their interactions under these parameters by ecological conditions of the growing sites. 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., 2003). Among the cultivars that are mostly used in new orchards of Turkey, 'Okitsu' and 'Clausellina' have been planting in the orchards established since the beginning and end of 1990s, respectively (Cinar, 2004). Kaplankiran et al. (2005) suggested avoiding the over-production during the harvest period when the prices are low; growers should focus on the 'Okitsu' and 'Clausellina' mandarins and 'Midknight Valencia' and 'Rhode Red Valencia' oranges.

Rootstocks have had a substantial role in the development of the citrus industry in the world. Rootstock utilization has gain value for solving both limiting and restricting factors of citrus production (soil, climate and pests, etc.) and conditioning the market demands on productivity, short juvenility period and high-fruit quality (Tuzcu et al., 1992). The rootstock may influence several aspects of citrus growth and development, including yield, fruit quality, and tolerance to stress caused by biotic and abiotic factors (Filho et al., 2007). The main rootstock in Turkey for citrus production is 'Sour Orange', while trifoliate orange, 'Troyer' and 'Carrizo' citrange are also used. The use of 'Carrizo' has been increased lately, especially in Eastern Mediterranean Region (Kaplankiran et al., 2001).

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This study was conducted to determine and compare the yield and fruit quality performances of three rootstocks for 'Rhode Red Valencia' and 'Valencia Late' in Eastern Mediterranean region of Turkey.

MATERIALS AND METHODS

The used rootstocks were 'Sour orange' (*Citrus aurantium* L. 'Yerli') and 'Carrizo' and 'Troyer' citranges (*Poncirus trifoliata* Raf. × *Citrus sinensis* (L.) Osb. 'Carrizo' and 'Troyer'). Trees were planted in 1998 at the Research Station of Mustafa Kemal University, Dörtyol (36º09' E; 36º51' N; 9 m a.s.l.), Turkey. The experimental design was a randomized complete blocks design with five replicates and a single-tree per plot. Trees were 7 m × 7 m apart under drip irrigation system and received the same cultural practices.

The soil texture of the plot located in Dörtyol (Hatay) was sandy-silt texture. The soil was course 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).

In January of each season, tree height, canopy diameter in the two tree directions (to obtain the average diameter), canopy circumference, trunk girth at 10 cm above and below the budding union were measured, and scion/stock girth ratio was calculated. 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).

Fruits per tree were collected and separately weighed so that the yield per tree (kg) could be calculated. The ratio of yield to CV (yield efficiency, kg m^{-3}) and the cumulative yield/tree were also calculated. Alternate bearing index (ABI) was calculated between the years 2007 and 2010, using the following expression (Monselise and Goldschmidt, 1982):

$$ABI = \frac{1}{n-1} \times \{ \frac{Ia_2 - a_1 I}{a_2 + a_1} + \frac{Ia_3 - a_2 I}{a_3 + a_2} + \cdots + \frac{Ia_n - a_{n-1} I}{a_n + a_{n+1}} \}$$

where n is number of years, and $a_1, a_2, ..., a_{n-1}, a_n$ are yields of the corresponding years.

Samples of 20 fruits per replicate were randomly collected at harvest date for determining physical and chemical characteristics. Individual fruit weight, fruit diameter, rind thickness, number of seeds per fruit, juice content, total soluble solids or °Brix, titratable acidity (TA) and then °Brix/TA ratio were determined.

Data recorded in all seasons were subjected to ANOVA using SAS program (SAS Institute, 1999) and means were compared with Tukey test at 5% level of significance.

RESULTS AND DISCUSSION

Plant growth

At 12 yr-old, trunk cross-sectional area (TCSA) and canopy projection area of both 'Rhode Red Valencia' and 'Valencia Late' orange trees on 'Troyer' citrange were significantly lower than those on 'Carrizo' citrange and sour orange (Table 1). Similar results were reported by Georgiou and Gregoriou (1999) on 'Shamouti' orange, who stated that 'Troyer' citrange induced the lowest values of TCSA as compared with 'Carrizo' citrange and sour orange, while Georgiou (2002; 2004) found that TCSA of 'Clementine' mandarin and 'Valencia' orange trees budded on 'Carrizo' and 'Troyer' citranges was similar, and lower than those on sour orange.

The largest canopy height of 'Valencia Late' orange trees were on 'Carrizo', although canopy heights of 'Rhode Red Valencia' orange trees were not significantly different according to rootstocks. Canopy diameters of both scion cultivars trees on 'Carrizo' were significantly larger than other rootstocks (Table 1). The results agreed with 'Carrizo' rootstock promoted higher canopy height and diameter than other rootstocks on 'Orlando' tangelo (Fallahi et al., 1991).

The canopy volume (CV) of 'Rhode Red Valencia' and 'Valencia Late' on 'Carrizo' were approximately 34% and 12% higher, respectively, than those on 'Troyer' (Table 1). Our CV findings are in harmony with those of Hutchison and Hearn (1977) on 'Robinson' and 'Page' mandarin trees; and those of Auler et al. (2008) on 'Valencia' orange

Table 1. Effect of rootstock on some plant characteristics of different "Valencia" clone trees in 2010.

Cultivar	Rootstock	Trunk cross-sectional area	Canopy projection area	Canopy height	Canopy diameter	Canopy volume	Scion:stock ratio[1]
		cm^2	m^2	m		m^3	
Rhode Red Valencia	Sour orange	234.37a	11.58ab	3.34	3.84ab	24.29	0.92
	Carrizo	243.27a	12.56a	3.40	4.00a	26.55	0.89
	Troyer	197.53b	10.76b	3.40	3.70b	23.65	0.89
HSD		18.53	1.27	NS	0.18	NS	NS
Valencia Late	Sour orange	242.55a	12.27a	3.32ab	3.93ab	25.88a	0.90
	Carrizo	242.05a	12.69a	3.43a	4.01a	27.10a	0.85
	Troyer	172.61b	10.62b	3.04b	3.67b	20.25b	0.89
HSD		39.14	1.45	0.28	0.26	4.10	NS

Means in the same column followed by different letters are significantly different according to Tukey's New Multiple Range test ($p \leq 0.05$).
NS: Non significant; HSD: Honestly significant difference.
[1]Ratio of scion trunk circumference to rootstock trunk circumference.

trees budded on different rootstocks, who found that the lowest CV was with 'Troyer'. Further, Gonzalez-Velez et al. (2002) mentioned that CV and canopy height of 'Orlando' tangelo trees was not affected by the rootstocks. These characteristics of rootstocks must be considered to determine in row and spacing of the row in establishing the orchard.

Rootstock influence on scion:stock ratio was statistically similar, although the most favorable rootstocks for 'Rhode Red Valencia' and 'Valencia Late' were sour orange (Table 1). Similar results were also obtained on 'Valencia' (Hassan et al., 2000) and 'Shamouti' oranges (Georgiou and Gregoriou, 1999) and 'Nova' (Georgiou, 2000), 'Clementine' (Georgiou, 2002) and 'Marisol' mandarins (Bassal, 2009).

Yield

The fruit yield was affected by the rootstock in both scion cultivars, from 2007 through 2010, except for 'Valencia Late' in 2009. Trees on 'Troyer' had lower yield than those budded on the other rootstocks. The yield of 'Rhode Red Valencia' and 'Valencia Late' orange trees on 'Carrizo' were about 9% and 19% more than those on 'Troyer', respectively. Yield of the trees on sour orange were found between 'Carrizo' and 'Troyer' rootstocks (Table 2). Similar results were also obtained by Georgiou (2002), who found that mandarin trees on 'Carrizo' were more productive than those on 'Troyer'. On the contrary, 'Olinda Valencia' (Al-Jaleel and Zekri, 2002) and 'Parent Washington Navel' (Al-Jaleel and Zekri, 2003) oranges were reported to yield similarly on sour orange and 'Carrizo' rootstocks. 'Carrizo' rootstock promoted higher yield compared to other rootstocks (Rouse, 2003; Tuzcu et al., 2004; Kaplankiran et al., 2005). Further, Filho et al. (2007) mentioned that fruit yield of 'Fallglo' and 'Sunburst' mandarin trees was not affected by the rootstock. All these results indicated the inconsistency in yield differences as affected by rootstocks, which could be attributed to differences in scion cultivars, tree age, climatic conditions, and soil characteristics, etc.

Having lower CV, trees on 'Troyer' had significantly higher yield efficiency than trees on sour orange and 'Carrizo' (Table 2). The lower yield efficiency on sour orange and 'Carrizo' is probably caused by the bigger canopy size induced by these rootstocks. The higher yield efficiencies were also reported for trees reduced in size by rootstocks (Roose et al., 1989; Auler et al., 2008).

'Rhode Red Valencia' orange trees on 'Troyer' showed significant ABI, however, no significant differences were found among these rootstocks for 'Valencia Late' (Table 2), which is supported by previous studies (Georgiou, 2000; 2002; Filho et al., 2007). The ABI may be reduced with the control of the crop load during the 'on' years by cultural practices, such as fruit thinning, branch girdling, exogenous application of plant growth regulators, and early harvest (Sposito et al., 1998).

Fruit quality

The juice content, total acids (TA), °Brix:TA ratio and number of seeds per fruit were not affected by the rootstock, in both scion cultivars. The fruit weight was higher in fruits of 'Valencia Late' trees budded on 'Carrizo' (214.69 g), while 'Rhode Red Valencia' trees (between 180.22 and 186.98 g) did not show any differences regarding the rootstock for this variable (Table 3). The results for 'Rhode Red Valencia' are in agreement with those of Myhob et al. (1996) on 'Valencia' orange; Gonzalez-Velez et al. (2002) on 'Orlando' tangelo, and Filho et al. (2007) on 'Fallglo' and 'Sunburst' mandarins, who reported that fruit weight was not affected by the rootstock. Auler et al. (2008) on 'Valencia' orange trees budded on six rootstocks declared that the trees on 'Troyer' produced smaller fruit than those on other rootstocks. Al-Jaleel and Zekri (2002) on 'Olinda Valencia' orange trees budded on nine rootstocks; and Auler et al. (2008) on 'Valencia' orange trees budded on six rootstocks reported that the fruit weight was determined in the range of 188.4-239.8 and 164.2-183.7 g, respectively.

The higher values of fruit diameter were verified in fruits of 'Rhode Red Valencia' orange trees on 'Carrizo' and 'Troyer', however 'Valencia Late' on 'Carrizo' had the least fruit diameter. The highest rind thickness was also obtained in fruits of 'Rhode Red Valencia' on 'Troyer' and those of 'Valencia Late' on 'Carrizo' and 'Troyer' (Table 3).

Table 2. Effect of rootstock on yield according years, cumulative yield, yield efficiency (yield in 2010 per tree volume) and ABI of different "Valencia" clone trees.

Cultivar	Rootstock	Yield (kg per tree)					Yield efficiency	ABI
		2007	2008	2009	2010	Cumulative 2007-2010		
							kg m^{-3}	%
Rhode Red Valencia	Sour orange	84.2a	81.0a	126.0ab	145.2b	436.4a	6.06b	0.11b
	Carrizo	84.4a	81.0a	109.4b	164.4a	439.2a	6.21ab	0.18ab
	Troyer	59.8b	56.3b	134.0a	152.6ab	402.7b	6.70a	0.26a
HSD		15.06	15.53	20.19	14.04	26.54	0.58	0.08
Valencia Late	Sour orange	42.5a	70.8a	100.4	165.2b	378.9a	7.15b	0.27
	Carrizo	45.3a	68.5a	107.2	182.0a	403.1a	6.80b	0.25
	Troyer	26.8b	50.5b	97.8	162.4b	337.5b	8.68a	0.28
HSD		5.99	11.95	NS	10.69	27.87	0.96	NS

Means having the different letters in each column are significantly according to Tukey test ($p \leq 0.05$).
NS: Non significant; ABI: Alternate bearing index; HSD: Honestly significant difference.

Table 3. Effect of rootstock on fruit quality of different "Valencia" clone (Average 2007-2010).

Cultivar	Rootstock	Fruit weight	Fruit diameter	Rind thickness	Juice content	°Brix	Total acids (TA)	°Brix: TA ratio	Number of seeds per fruit
		g	mm			%			
Rhode Red Valencia	Sour orange	180.22	69.57b	4.01b	50.60	9.09a	1.29	7.12	3.38
	Carrizo	186.98	72.59a	4.16b	50.09	9.00a	1.23	7.20	3.51
	Troyer	185.36	72.05a	4.53a	49.17	8.82b	1.25	7.14	3.01
HSD		NS	2.42	0.29	NS	0.17	NS	NS	NS
Valencia Late	Sour orange	195.84b	75.25b	3.98b	47.88	9.23	1.37	6.76	4.78
	Carrizo	214.69a	80.15a	4.85a	49.23	9.22	1.36	6.77	4.77
	Troyer	187.68b	77.11b	4.69a	48.24	9.14	1.34	6.80	4.74
HSD		9.40	2.54	0.50	NS	NS	NS	NS	NS

NS: Non significant; HSD: Honestly significant difference.
Means having the different letters in each column are significantly according to Tukey test ($p \leq 0.05$).

The rootstocks had no significant effects on juice content of 'Rhode Red Valencia' and 'Valencia Late', which is ranged between 49.17-50.60% and 47.88-49.23%, respectively. Gregoriou and Economides (1993) on 'Ortanique' tangor; Tuzcu et al. (2004) on 'Washington Navel' orange; and Filho et al. (2007) on 'Fallglo' and 'Sunburst' mandarins mentioned that fruit juice content was not affected by the previous studies on rootstock. Al-Jaleel and Zekri (2002) on 'Olinda Valencia' orange in Saudi Arabia and Auler et al. (2009) on 'Valencia' orange in Brazil conditions reported that fruits on nine rootstocks had juice content ranged between 51.1-53.7% and 48.8-51.3%, respectively.

Although the °Brix was not significantly different by the rootstocks on 'Valencia Late', it was lower in fruits of 'Rhode Red Valencia' on 'Troyer' (Table 3). The results obtained by 'Valencia Late' are in agreement with those of Hearn (1987) on 'Fallglo' mandarin and Hearn (1989) on 'Ambersweet' orange, who found that the fruits on 'Carrizo' had similar °Brix those on sour orange. °Brix findings provided from this study were lower than the results of Al-Jaleel and Zekri (2002) on 'Olinda Valencia' and Auler et al. (2009) on 'Valencia' oranges reported that fruits on all rootstocks had Brix between 11.8% and 13.7%, and between 10.3% and 11.4%, respectively.

The total acids of both 'Rhode Red Valencia' and 'Valencia Late' orange trees were not affected by the rootstocks (Table 3). Myhob et al. (1996) on 'Valencia'; Tuzcu et al. (2004) on 'Washington Navel' orange; Demirkeser et al. (2005) on 'Rhode Red Valencia' orange; Kaplankiran et al. (2005) on 'Okitsu' Satsuma mandarin; and García-Sánchez et al. (2006) on 'Clemenules' mandarin found that the effects of the rootstocks on fruit juice acidity were insignificant.

CONCLUSIONS

Both scion cultivars displayed high yield efficiency and weak growth on 'Troyer' citrange, which may be better suited to high density plantings. On the other hand, 'Carrizo' citrange and sour orange seems to be more suitable rootstock in terms of yield per tree for the cultivars used in this study. Fruit quality of Rhode Red Valencia was similar for each rootstock used in this experiment, but it was higher on 'Carrizo' citrange in 'Valencia Late' orange. At present in Turkey, sour orange is the most commonly used rootstock for the commercial cultivation of 'Valencia Late' orange but it is highly susceptible to *Citrus tristeza virus*. The results showed that 'Carrizo' and 'Troyer' citranges, which is supported by previous research, were very promising as alternative rootstocks. However, further studies in different locations with different conditions are needed, and the current study should be prolonged to see the effects age of the tree.

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