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Yield and fruit quality performance of Nova and Robinson mandarins on three rootstocks in Eastern Mediterranean

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Yield and fruit quality performances of Nova and Robinson mandarins were evaluated in the Mediterranean climate of Dörtyol, Hatay, Turkey from 2002 to 2007. The cumulative yields of both Nova and Robinson mandarins over this 6 year production period were highest on Carrizo citrange and smallest on Troyer citrange. The fruit weight and seed content were affected by the rootstock in Nova mandarin. The heaviest fruits were obtained from Troyer citrange. For Robinson mandarins, the fruit weight and size were not affected by the rootstock, whereas the fruit color and skin structure were found to be affected by the rootstocks. In the two mandarin cultivars evaluated, the rind thickness, juice content, total soluble solids (TSS), total acidity (TA) and TSS/TA ratio were similar when the rootstocks were compared. For Nova and Robinson mandarins, all of the rootstocks gave good fruit quality for the fresh fruit markets in the Eastern Mediterranean region. In conclusion, we propose Carrizo and Troyer citranges as an alternative to sour orange rootstocks.

Key words: Mandarin, carrizo citrange, sour orange, troyer citrange, mediterranean.

INTRODUCTION

World production of mandarins (*Citrus reticulata* L. Rutaceae) is on the rise. The world total citrus production has increased by 8.3% in the last 10 years, reaching 114,878,542 tons. Among citrus species, mandarin production has increased by 34.7% (FAO, 2006). Mandarins are "easy-peelers" and so-called "child's fruit" because they have a sweet flavor and aroma, loose skins, a smaller fruit-size among the edible citrus and are easy to peel and separate into segments.

The mandarin is adaptable to a wide range of climates and is grown under desert, -semi-tropical and sub-tropical Mediterranean conditions (Tous and Ferguson, 1992), yet the climate in which mandarins are grown greatly influences the fruit quality. The excellent quality and characteristic flavor of the mandarin cultivars are highly prized by some, and if seedless varieties of a larger size can be

developed, their popularity will greatly increase. Over the last decade, mandarin production in Mediterranean countries has increased by 21.2% (FAO, 1997; FAO, 2006) and substantial increases are expected in Spain, Turkey and Egypt. Over the same period, Turkish citrus production was about 2,587,650 tons and exhibited a 2.7 fold higher increase relative to the increase in the world citrus production. Turkey's mandarin production, in particular, reached 585,000 tons, a 29% increase over the last decade. Most Turkish mandarin production is conducted in the Mediterranean region (76%), in which Adana (204.201 tons) and Hatay (163.527 tons) are important producing provinces. Hatay produces 22% of Turkey's citrus and 39% of Turkey's mandarins (Anonymous, 2005a). In the Mediterranean regions of Turkey, the most commonly grown mandarin cultivars are Owari Satsuma, Fremont, Nova and Robinson. In addition, the production of Okitsu and Clausellina Satsumas, Dobashi Beni, Nules, Marisol and Arrufatina Clementine have recently increased.

Among mandarin cultivars, Nova is a hybrid of the Fina

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Clementine Orlando tangelo cross that was made in 1942. The rind color of Nova is a more attractive reddish-orange and its internal quality is extremely high. The color is a deep orange and the segments are very juicy and tender and have a fine sweet flavor. Acid levels are moderate, resulting in a high sugar to acid ratio. Nova is popular with consumers who are prepared to pay premium prices only if the fruit is seedless and seedless fruits are also preferred in European markets. Burdette (1993) reported that the use of a suitable pollinator is the most efficient method for producing incompatible cultivars such as Nova mandarin, in terms of fruit yield and quality. In recent years, production of mandarins, such as Nova, has been increasing in Turkey.

Robinson is derived from a cross between a Clementine and Orlando tangelo that was made by F.C. Gardner and J. Bellows in Florida in 1942. Robinson is a very early maturing hybrid. Its size is similar to the Dancy tangerine and its external and internal color reaches a deep rich orange color. The quality of Robinson fruit is excellent (Saunt, 1990), and it possesses the typical mandarin characteristic of an easily separable peel (Davis and Albrigo, 1994). Robinson requires cross-pollination with compatible cultivars, but fruit are also produced parthenocarpically. Seed number varies from 0 - 20 per fruit, depending on cross-pollination and Robinson trees are moderately vigorous and productive and exhibit only weak periodicity (Tuzcu, 1990).

The latest trend in the citrus industry is to extend the period in which the markets are supplied with citrus fruits, particularly oranges and mandarins. For this reason, fruit exporting companies of Turkey have proposed that growers use early and late cultivars. The characteristics of preferred mandarin cultivars include deep colored fruit, larger fruit, low seed number and easy-peeling (Kaplan-kiran et al., 2005a; Filho et al., 2007). In addition to these characteristics, both growers and breeders have focused on novel early and late cultivars.

With changes in customer preferences, many new citrus cultivars have been introduced to Turkey. However, all are not expected to perform equally well, since various ecological and climatic conditions exist in Turkey. It would therefore be useful to identify favorable ecological conditions for individual cultivars. In addition, factors such as cultivar characteristics, rootstocks employed and growing conditions.

Rootstock utilization has gained value for solving the limiting factors of citrus production (soil, climate and pests etc) and conditioning of market demands (fresh or processed) on productivity, short juvenility period and high fruit quality. In Turkey, the main rootstock utilized is sour orange, which is the dominant rootstock in the Mediterranean region, where 88% of citrus fruits are produced; whereas trifoliate oranges are the dominant root-

stock in the Aegean and Black Sea regions. However, the use of Carrizo has increased lately, especially in the Eastern Mediterranean region (Kaplan-kiran et al., 2001). To deal with potential problems of *Citrus tristeza*, Turkey has initiated a research program to replace the susceptible sour orange with alternative rootstocks that are tolerant to *C. tristeza*. The present study therefore aims to evaluate the growth, yield and fruit quality of Nova and Robinson mandarins budded on three rootstocks in Turkey.

MATERIALS AND METHODS

Plant material and field trial

Rootstocks were propagated from seed which were obtained from the University of Çukurova Citrus and Subtropical Fruit Collection plots in Adana. Seeds were sown in plastic bags in February and October, 1997, the seedlings of sour orange (*Citrus aurantium* L.), Troyer and Carrizo citranges (*Citrus sinensis* L.) and Osbeck *Poncirus trifoliata* (L.) Raf.) were grafted with Nova and Robinson (*Citrus reticulata* Blanco x *Citrus paradisi* Macf. x *C. reticulata*) mandarins that were free of all known pathogens. Bud woods were obtained from the University of Çukurova Citrus and Subtropical Fruit Research Center. The grafted trees were subsequently planted at the Research Station of Mustafa Kemal University, Agricultural Faculty Citrus Experimental Station, Dörtüyl (Latitude, 36° 51.10 N; Longitude, 36° 09.57E and altitude 9 m). The region has a Mediterranean climate with an annual average temperature of 19.1°C and an annual rainfall of 950 mm (Anonymous, 2005b). Horticultural crops are prevalent in the research area and the most common crops include subtropical and Citrus species (mandarin, orange and grapefruit).

Experimental design and cultivation

The experimental design was a completely randomized one with five replicates and a single tree per plot. Trees were planted with 7 × 7 m spacing in 1998. The experimental plantation was not isolated; rather, it was surrounded by various other Citrus cultivars, such as Okitsu, Clausellina, Silverhill 22 - 9, Rhode Red Valencia, Mid-knight Valencia and Valencia Late. Valencias were suitable pollinator for Nova and Robinson and they are planted at uniform pollination distance. The soil texture of the plot located in Dörtüyl (Hatay) had a sandy-silt texture.

The soil was coarse-textured (sand, 64.6 - 69.3; silt, 24.5 - 27.0 and; clay, 6.4 - 6.4 g/kg) 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 depths respectively in 1:2.5 soil water suspension) and rich in total limestone, 15.0% for 0 - 30 cm; 22.1% for 30 - 60 cm and; 19.0% for 60 - 90 cm depth.

Standard culture techniques were used with mechanical weed control between rows and chemical control between trees. In the first three years of culture, trees were pruned. After 4 years of culture, the trees were annually hand-pruned in January. Drip irrigation was installed with frequency adjustments according to the season of the year, using a 2 - 3 day interval (in summer) per week with 40 L/tree in each irrigation. Fertilizer was applied with irrigation water starting in the second year and application was increased annually. In 2004, the trees were fertilized with 500 g N/tree ($\frac{1}{2}$ of it at the end of February, $\frac{1}{4}$ at the end of May and $\frac{1}{4}$ at the beginning of July), 300 g P/tree (in December) and 300 g K/tree (by the end of

Table 1. Annual and cumulative yield traits of Nova mandarin trees on three rootstocks in Dörtöyl, Turkey (2002-2007).

Rootstock	Yield (kg / tree)						Cumulative
	2002	2003	2004	2005	2006	2007	
Sour orange	22.15b	39.95b	42.65	82.79a	83.62b	93.00	364.17 b
Carrizo	27.44a	76.95a	47.33	86.52a	75.25b	92.40	405.89 a
Troyer	17.27c	31.85b	40.81	66.37b	100.43a	88.33	345.06 b
Significance ¹	**	**	NS	**	**	NS	**
D _{0.05}	4.15	18.82	---	13.16	13.17	---	26.35

¹NS, *, ** represent non significant and significant at 5 and 1%, respectively.

January). Foliar nutrient application and pest and disease management were conducted in accordance with normal commercial practices guided by the Department of Horticulture and Plant protection.

Yield, fruit quality, and growth measurements

Between 2002 - 2007, the fruits of each tree were harvested and weighed for Nova on the 10th of December and for Robinson at the end of November. 20 fruits per tree were randomly collected and analyzed for quality. Fruits were weighed, and fruit diameter and rind thickness were determined with a digital caliper. Juice was extracted with an electric squeezer. The juice content (%), TSS (determined with an Atago ATC-1E model hand refractometer (at 20°C), and total acids (TA) were measured (as citric acid equivalent per 100 ml) by titration of 5 ml of fruit juice with 0.1 N NaOH to pH 8.1 (Sadler, 1994). Rind color was determined on a 1 - 7 scale (1 - 4 light to dark green; 5 orange; 6 dark orange; 7 reddish orange).

In January, the height, canopy diameter and trunk circumference (10 cm above the bud union) were measured. Canopy volume (CV) was calculated from canopy height and spread; consider canopy as a prolate spheroid and applying the formula (Westwood, 1993):

$$CV = \frac{4}{3} \pi ab^2$$

Where:

The major axis = length/2 (a).

The minor axis = length/2 (b)

The trunk circumference was converted into trunk cross-sectional area (TCSA). The yield efficiency was estimated as the ratio of yield to canopy volume (kg/m³), trunk cross-sectional unit area (kg/cm²), yield/canopy projectional unit area (kg/m²) and cumulative yield (kg/tree).

Data analyses

The data were analyzed using SAS procedures (SAS, 2005). The GLM procedure was used to construct analysis of variance tables. When the factors were significant at 5% and 1% levels, the means were separated using Duncan's multiple range test at P = 0.05.

RESULTS AND DISCUSSION

Yield

For the cumulative yield based on a six-year period, Car-

rizo citrange had significantly greater yield than sour orange and Troyer citrange in Nova. Troyer had lower yield than Carrizo and sour orange rootstocks in Robinson (Tables 1 and 2). Yield means except 2004 and 2007 showed significant differences among the rootstocks in Nova mandarin. However, Carrizo had the greatest yields for 2002, 2003 and 2007 (Table 3). The rootstocks significantly affected yield parameters for (Table 3). Except 2005 - 2006, Carrizo and sour orange had the highest yields. For Nova, the effects of rootstocks on yield parameters were measured and the average over the 6 year period; sour orange (12.03 kg/m³) and Troyer citrange (11.52 kg/m³) had the greatest yield canopy volume. For yield expressed in trunk cross sectional area, Troyer (15.72 kg/m²) and sour orange (14.89 kg/m²) were in the same mean groups. However, for Robinson, no statistically significant differences were detected for rootstocks' effects on yield (Table 3).

Nova trees on Carrizo differed significantly from sour orange and Troyer citrange and had the highest cumulative yield; however, sour orange and Troyer were not significantly different from each other in Nova mandarin. Georgiou (2000) reported in an 11 year study that sour orange had higher cumulative yields when compared to Carrizo and Troyer citranges. In the present study, Troyer had less cumulative yield than Carrizo citrange. In a 2 year study by Temiz (2005), the greatest yield was recovered from Carrizo citrange for Nova.

Troyer had a lower yield than Carrizo or sour orange rootstocks in Robinson. Matyar (1992) reported that Robinson had high yields and quality parameters on sour orange. Temiz (2005) observed the greatest yield of Robinson grafted on sour orange. Tuzcu et al. (1995) studied the effects of 9 rootstocks on Owari Satsumas and found that Carrizo citrange, Sitrumelo 1452 and Yuzu gave the most promising results in terms of yield and quality. Based on their results, they proposed Carrizo as an alternative to sour orange for the Mediterranean region of Turkey. For Nova, yield to canopy volume, trunk cross sectional unit area and yield /canopy projectional

Table 2. The annual and cumulative yield traits of Robinson mandarin trees on three rootstocks in Dörtyol, Turkey (2002-2007).

Rootstock	Yield (kg/tree)						Cumulative
	2002	2003	2004	2005	2006	2007	
Sour orange	15.39b	37.59b	40.54a	71.99a	93.21b	120.96a	379.68 a
Carrizo	21.87a	58.75a	30.35b	60.81b	100.13ab	117.59a	389.50 a
Troyer	13.35b	23.79c	19.48c	80.04a	108.48a	94.19 b	339.33 b
Significance ¹	**	**	**	**	*	**	**
D _{0.05}	3.85	7.44	8.32	8.45	14.32	5.92	21.45

¹NS, *, ** represent non significant and significant at 5 and 1% respectively.

unit area were found to be highest for sour orange and Troyer citrange for the averages of 6 years. Although Carrizo gave the greatest yield averages on a per tree basis, these values were found to be lowest on Carrizo. Similar results were obtained by Kaplankıran et al. (2005b). These results may be explained by the greater canopy volume of trees grafted on Carrizo citrange when compared to those of other rootstocks tested.

Fruit quality

The fruit weight and seed content were affected by the rootstock in Nova mandarin (Table 4), whereas rootstocks had no effect on fruit diameter or rind thickness. The heaviest fruits were obtained from Troyer citrange (146.02 g), whereas Carrizo (136.54 g) and sour orange (135.25 g) were in the same mean group. Blondel (1986) on Clementines and Mendilcioğlu (1986) on Satsumas found that Troyer and Carrizo citranges had higher fruits when compared to sour orange.

The greatest seed number was recovered from sour orange (12.15 per fruit), whereas the lowest was from Troyer citrange (6.47 per fruit). When the effects of rootstocks were measured for an average of 6 years for Nova mandarin, no significant differences were detected for rind thickness, juice content, TSS, TA or TSS/TA ratios. However, some variables (juice content, TA, and TSS/TA ratios) were found to be significantly affected by rootstocks in specific experimental years.

The number of seeds was significantly influenced by the rootstocks in Nova and Robinson fruits. However, seed number did not reach commercially unacceptable levels. Georgiou (2000) reported similar results for seed numbers. Pollination and pollination efficiency are the most important factors for number of seeds per fruit (De Lange et al., 1973; Ferraro et al., 2006). The fact that the pollinators for both species were similar in this study may have contributed to similar numbers of seeds obtained from experimental plots.

Robinson's fruit weight and diameter were not affected

by the rootstocks (Table 5). Similar to Nova, no significant differences were found for fruit quality parameters tested when the means from the 6 year data were evaluated. However, the TA and TSS/TA ratios were found to be affected by the rootstocks in specific years.

Robinson's fruit weight and diameter were not affected by the rootstock. Filho et al. (2007) also reported that fruit weight and juice content of both mandarin cultivars were not influenced by the rootstocks. These results are similar to those of previous studies in which the fruit weight of Satsuma mandarin was not affected when budded on 10 different rootstocks (Salibe and Mischán, 1984). Reforgiata-Recupero and Russo (1983) reported that Clementine SRA-63 mandarin gave similar fruit weight and rind color on Troyer and Carrizo citranges when compared to sour orange.

No significant differences for rootstocks were found for rind thickness, juice content, TSS, TA or TSS/TA ratios, either in Nova or Robinson mandarins. Kaplankıran et al. (2005b) studied the effects of the same rootstocks on fruit quality parameters for Okitsu Satsumas and detected no significant differences. Filho et al. (2007) reported no differences in juice quality in two harvest seasons for Fallglo and Sunburst mandarin cultivars.

The rootstocks did not affect the skin structure, rind color or ease of peeling for Nova. However, skin structure and rind color of Robinson were found to vary for the rootstocks. For Robinson, sour orange gave smoother skins than Troyer; whereas Carrizo gave a darker rind color than Troyer. Similar results have been reported for Satsuma and Okitsu mandarins when the same rootstocks were compared in a similar environment (Tuzcu et al., 1995; Kaplankıran et al., 2005b; Temiz, 2005). Matyar (1992) and Urgan (1997) reported orange rind color for Robinson grafted on sour orange. Nova is a grown mandarin cultivar in the Mediterranean region of Turkey due to its superior quality characteristics such as early fruit production, high yield and low tendency for periodicity. Robinson is also a popular cultivar because of its high fruit set and resistance to cracking. Sour orange is the

Table 3. Various yield traits of Nova and Robinson mandarins on three rootstocks (2002-2007).

Year	Rootstock	Nova			Robinson		
		Yield to canopy volume (kg/m ³)	Yield to trunk cross-sectional unit area (kg/cm ²)	Yield/canopy projectional unit area (kg/m ²)	Yield to canopy volume (kg/m ³)	Yield to trunk cross-sectional unit area (kg/cm ²)	Yield/canopy projectional unit area (kg/m ²)
2002	Sour orange	10.80 a	2.03 a	10.83 a	5.09 b	1.83	5.87 b
	Carrizo	6.71 b	1.84 a	8.87 a	7.77 a	1.97	8.61 a
	Troyer	5.34 c	0.63 b	3.06 b	7.59 a	1.84	7.67 a
	Significance ¹	**	**	**	*	NS	*
	D _{0.05}	1.24	0.21	3.48	2.43	---	1.09
2003	Sour orange	22.83 a	2.40 a	22.49 a	10.60 b	1.45 ab	12.93 b
	Carrizo	16.17 b	1.84 a	22.82 a	20.69 a	1.82 a	22.61 a
	Troyer	9.71 c	1.00 b	12.57 b	11.15 b	1.15 b	11.89 b
	Significance ¹	**	**	*	**	*	**
	D _{0.05}	4.94	0.76	5.14	2.07	0.65	5.77
2004	Sour orange	12.81 a	1.02 a	13.56 a	10.63 a	0.76 a	13.30 a
	Carrizo	5.59 b	0.47 b	8.83 b	9.10 ab	0.48 b	10.75 ab
	Troyer	10.37 ab	0.49 b	12.45 ab	8.25 b	0.47 b	9.07 b
	Significance ¹	*	**	**	*	*	*
	D _{0.05}	6.11	0.46	4.33	1.98	0.27	3.71
2005	Sour orange	11.92 a	2.30 a	17.64 a	6.88 b	0.84 b	11.23 b
	Carrizo	7.03 b	0.87 b	13.83 b	8.16 b	0.67 b	12.39 b
	Troyer	9.16 ab	0.88 b	14.61 b	15.03 a	1.35 a	21.84 a
	Significant ¹	*	**	**	**	**	**
	D _{0.05}	4.78	0.63	2.61	4.02	0.25	4.89
2006	Sour orange	8.24 b	0.82 ab	13.23 b	14.14 b	0.81 b	20.64
	Carrizo	3.84 c	0.60 b	7.63 c	12.34 b	0.93 b	18.65
	Troyer	15.58 a	1.17 a	20.19 a	19.00 a	1.51 a	21.61
	Significance ¹	**	**	**	**	**	NS
	D _{0.05}	3.46	0.48	5.31	3.45	0.28	---
2007	Sour orange	5.61 b	0.54 b	11.59 b	16.41 a	0.89 ab	24.77 a
	Carrizo	4.44 b	0.60 b	9.07 b	11.86 b	0.80 b	20.84 ab
	Troyer	12.81 a	0.76 a	18.79 a	16.44 a	0.98 a	19.52 b
	Significance ¹	**	**	**	**	**	**
	D _{0.05}	2.65	0.06	5.18	4.27	0.10	5.13
Mean	Sour orange	12.03 a	1.52	14.89 a	10.62	1.09	14.79
	Carrizo	7.30 b	1.04	11.84 b	11.65	1.11	15.64
	Troyer	11.52 a	0.86	15.72 a	12.91	1.21	15.27
	Significance ¹	**	NS	**	NS	NS	NS
	D _{0.05}	1.86	---	2.69	---	---	---

¹NS, *, ** represent non significant and significant at 5 and 1%, respectively.

dominant rootstock in the Eastern Mediterranean where 88% of citrus fruits are produced. This fact might be due to the fact that growers insist on the rootstock that they are accustomed to for achieving good performance from sour orange. Because sour orange is highly susceptible to *C. tristeza*, several studies have been performed since

the 1980s to identify alternative rootstock. The present study demonstrated that Nova and Robinson produce fruits with quality (high juice quality and good fruit external appearance on all rootstocks) sufficient for both fresh fruit market and industry. For both mandarin cultivars tested, Carrizo citrange appeared to be superior for yield

Table 4. The effects of three rootstocks on pomological characters of Nova mandarin in Dörtöyl, Turkey (2002-2007).

Rootstock	Fruit weight (g)	Fruit diameter (mm)	Rind thickness (mm)	Seed no. (no./fruit)	Juice content (%)	Soluble solids (%)	Acidity (%)	Soluble solids/ acidity	Skin structure ²	Rind color ³	Ease of peeling ⁴
Sour orange	135.25b	65.17	2.83	12.15 a	50.67	11.92	1.01	11.98	2.00	6.07	3.97
Carrizo	136.54b	65.68	3.08	9.38 b	50.59	12.02	0.98	12.44	2.07	5.97	3.80
Troyer	146.02a	65.74	3.07	6.47 c	50.16	11.70	1.09	11.06	1.93	6.10	3.80
Significance ¹	**	NS	NS	**	NS	NS	NS	NS	NS	NS	NS
D _{0.05}	9.14	---	---	2.24	---	---	---	---	---	---	---

¹NS, *, ** represent non significant and significant at 5 and 1%, respectively. ²1: rough; 2: medium; 3: smooth.³1: green - 5: orange; 6: dark orange; 7: reddish orange. ⁴1: Very easy; 2: easy; 3: somewhat tight; 4: tight.

Table 5. The effects of three rootstocks on pomological characters of Robinson mandarin in Dörtöyl, Turkey (2002 – 2007).

Rootstock	Fruit weight (g)	Fruit diameter(mm)	Rind thickness(mm)	Seed no. (no./fruit)	Juice content (%)	Soluble solids (%)	Acidity (%)	Soluble solids/ acidity	Skin structure ²	Rind color ³	Ease of peeling ⁴
Sour orange	136.92	64.73	3.24	9.62 b	50.19	12.11	1.05	11.67	2.67 a	5.ab	3.17
Carrizo	137.30	63.62	2.99	11.50 a	51.26	11.73	1.06	11.40	2.00 b	5.9a	3.03
Troyer	139.08	65.86	3.03	8.72 b	51.90	11.80	1.08	11.22	2.23 ab	5.4b	3.03
Significance ¹	NS	NS	NS	**	NS	NS	NS	NS	**	*	NS
D _{0.05}	---	---	---	2.15	---	---	---	NS	0.61	0.35	---

¹NS, *, ** represent non significant and significant at 5 and 1%, respectively. ²1: rough; 2: medium; 3: smooth. ³1: green - 5: orange; 6: dark orange; 7: reddish orange. ⁴1: Very easy; 2: easy; 3: somewhat tight; 4: tight.

characteristics. The fruit characteristics of the citranges were comparable to those of sour oranges. We therefore propose Carrizo and Troyer citranges as alternatives to sour orange rootstocks.

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