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Performances of 'Okıtsu' and 'Clausellına' Satsuma Mandarıns on Dıfferent Rootstocks in Eastern Medıterranean of Turkey

Farklı Anaçlar Üzerine Aşılı 'Okitsu' ve 'Clausellina' Satsuma Mandarin Çeşitlerinin Türkiye'nin Doğu Akdeniz bölgesindeki Performansları

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Citrus unshiu Marc., çeşit, taç gelişimi, verim etkinliği, meyve kalitesi

ABSTRACT

The experiment was installed in Dörtyol, Turkey with the aim of evaluating the effects of the rootstocks of sour orange, Carrizo and Troyer citranges on plant growth, yield and fruit quality of 'Okitsu' and 'Clausellina' Satsuma mandarins (*Citrus unshiu* Marc.). 'Okitsu' Satsuma trees had the highest cumulative yield on Carrizo and Troyer citranges. Plants of this cultivar on sour orange had significant higher yield efficiency than trees on the other rootstocks. While 'Clausellina' Satsuma trees budded on Carrizo citrange had higher cumulative yield, yield efficiency of this cultivar had higher on Troyer citrange. The larger trees of 'Clausellina' Satsuma were those on Carrizo citrange, although canopy growth of 'Okitsu' Satsuma tress budded on Carrizo and Troyer citranges were similar. Fruit weight was highest in fruits of both 'Okitsu' and 'Clausellina' Satsuma cultivars budded on sour orange. The rind thickness and total soluble solids (TSS) of both cultivars were not affected by the rootstocks. The fruits of 'Okitsu' Satsuma trees on Carrizo citrange had higher juice content and high TSS:titratable acidity (TA) ratios were observed in fruits of 'Clausellina' Satsuma trees on Carrizo citrange. Instead of sour orange, Troyer citrange is suitable rootstocks for 'Clausellina' Satsuma, whereas both rootstocks evaluated are adequate for 'Okitsu' Satsuma.

ÖZET

Deneme, 'Okitsu' ve 'Clausellina' (*Citrus unshiu* Marc.) Satsuma mandarin çeşitlerinin turunç, Carrizo ve Troyer sitranjı anaçları üzerindeki bitki gelişimi, meyve verim ve kalitesi üzerine etkilerini değerlendirmek amacıyla Dörtyol'da kurulmuştur. Çalışmada, 'Okitsu' çeşidinde en yüksek kümülatif meyve verimi Carrizo ve Troyer sitranjı anaçları üzerinde belirlenirken, verim etkinliği yönünden turunç anacı diğer anaçlara göre daha yüksek değerler göstermiştir. 'Clausellina' çeşidinde en yüksek kümülatif verim Carrizo sitranjı üzerinde belirlenirken, verim etkinliği Troyer sitranjı üzerinde daha yüksek bulunmuştur. 'Okitsu' çeşidinde Carrizo ve Troyer sitranjı anaçları benzer taç büyüklüğü gösterirken, 'Clausellina' çeşidinde en büyük taçlı ağaçlar Carrizo sitranjı üzerinde belirlenmiştir. Meyve ağırlığı hem 'Okitsu' hemde 'Clausellina' çeşitlerinde turunç anacı üzerindeki ağaçlarda daha yüksek elde edilmiştir. Her iki çeşidin meyvelerinde kabuk kalınlığı ve suda çözünebilir kuru madde (SÇKM) miktarı anaçlar tarafından istatistiki olarak etkilenmemiştir. 'Okitsu' çeşidininde Carrizo sitranjı üzerindeki meyveler daha yüksek usare içeriğine sahip olmuştur. 'Clausellina' çeşidinde meyvelerin SÇKM/asit içeriğinin Carrizo sitranjı üzerine aşılı ağaçlarda daha yüksek olduğu gözlenmiştir. Çalışma sunucunda, turunç anacına alternatif olarak 'Clausellina' çeşidinde Troyer sitranjı, 'Okitsu' çeşidinde ise hem Carrizo sitranjı hemde Troyer sitranjı anacının kullanılabileceği değerlendirilmiştir.

INTRODUCTION

The citrus production of Turkey has reached at 3 181 359 tons in 2014, with an increase of 80% in last 20 years. Total citrus production of Turkey is composed of orange the first (1 779 675 tons), mandarin the second (1 046 899 tons) and lemon the third (725 230 tons) species (FAOSTAT, 2014). Satsuma mandarin (*Citrus unshiu* Marc.) represents 86% of the

total mandarin production in Turkey. 'Owari' is the main Satsuma in Turkey; however, 'Okitsu' in early 1990's and 'Clausellina' in late 1990's have been planted in the orchards (Cinar, 2004). 'Okitsu' is obtained form a nuceller seedling from a controlled pollination of 'Miyagawa'. It is earlier than both 'Miyagawa' and 'Owari' and has lower acidity and relatively higher soluble solids (Saunt, 1990; Davies and Albrigo, 1998). 'Clausellina', a bud mutation from 'Owari' reaches acceptable maturity about three weeks ahead of 'Owari'. However, the quality and sweetness are lower, when fully mature. 'Clausellina' is much more popular than 'Owari' on account of its earlier maturity. Kaska et al. (2005) suggested the use of 'Okitsu' and 'Clausellina' Satsuma mandarins to extend the harvest period and to avoid marketing problems in both domestic and foreign markets.

The rootstock could affect many features of citrus growth and development, consisting yield, fruit quality, and tolerance to stress caused by biotic and abiotic factors (Filho et al., 2007). Trifoliate orange, Troyer and Carrizo citranges are also used, however the main rootstock of Turkish citrus production is sour orange, highly susceptible to tristeza virus (Wallace, 1956; Salibe, 1974). The problem of tristeza in Turkey 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 utilization of Carrizo citrange has been raised recently notably in Eastern Mediterranean Region of Turkey. Trifoliate orange was used in old Satsuma orchards of Aegean Region of Turkey (Kaplankiran et al., 2005).

This paper focused on finding the performance of 'Okitsu' and 'Clausellina' Satsuma mandarins budded on three rootstocks and evaluate the results to make suggestions to region's growers in the Dörtyol, Eastern Mediterranean Region, Turkey.

MATERIAL and METHOD

Plant Material and Field Trial

'Okitsu' and 'Clausellina' Satsuma mandarins were budded on sour orange (*C. aurantium* L. var. 'Yerli'), Carrizo and Troyer citranges (*C. sinensis* (L.) Osb. X *Poncirus trifoliata* (L.) Raf.) rootstocks. The experiment was carried out at Dörtyol Research Station (Longitude, 36° 09' E; Latitude, 36° 51' N; Elevation: 9 m above sea level), Mustafa Kemal University, Faculty of Agriculture, with soil conditions described as sandy-silt texture. The soil had characteristics of 17.6% coarse sand, 37.6% fine sand, 23.8% silt, 22% clay and slightly alkaline to alkaline in the soil profile. The pH levels were 7.80, 7.98 and 8.25 for 0–30, 30–60 and 60–90 cm depth, respectively, 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 climate, according to Köppen climate classification, is of the Csa type (subtropical with moderate and rainy winters, hot and dry summers), with 23.1°C yearly maximum temperature, 14.0°C yearly minimum temperature, 18.2°C yearly average temperature, and 729.6 mm annual rainfall. In the horticultural research station, the most common crops are subtropical and citrus species (mandarin, orange and grapefruit). Trees were planted in November 1998 and February 1999. The experimental orchard was encircled by several other citrus such as 'Silverhill 22-9', 'Fremont', 'Nova', 'Robinson', 'Rhode Red Valencia', 'Midknight Valencia' and 'Valencia Late'.

Growth measurements, fruit yield and quality characteristics

In order to obtain the mean diameter, and canopy height and canopy diameter in the two tree directions were calculated after harvesting in each season at the end of December. By 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, the canopy volume (CV) was measured from canopy height and spread (Westwood, 1993). Besides, stock and scion trunk circumferences were calculated as 10 cm below and above the bud union and their scion/stock ratio was measured. 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 13th year after planting (YAP).

The alternate bearing index (ABI) was measured by taking into consideration fruit yield between the 9th YAP and the 13th YAP, using the expression below (Monselise and Goldschmidt, 1982):

$$ABI = \frac{1}{n-1} x \left\{ \frac{|a_2 - a_1|}{a_2 + a_1} + \frac{|a_3 - a_2|}{a_3 + a_2} + \cdots + \frac{|a_n - a_{n-1}|}{a_n + a_{n+1}} \right.$$

The n in the formula symbolizes number of years, and a_1, a_2, ..., a_{n-1}, a_n represent yields of the corresponding years.

Harvest occurred on the late September of each year. Total fruit mass production was registered for each plant. The cumulative yield/tree was calculated for the 9th YAP through the 13th YAP (5-years cumulative yield).

In all five experimental years, 20 fruits per tree were collected to evaluate fruit quality. Fruits were weighed, and fruit diameter and rind thickness were determined with a digital caliper. Fruit juice was extracted with an electrical squeezer. The juice content (%) was measured

by the relation juice weight: fruit weight. Total soluble solids (TSS) content was identified by direct reading in a hand refractometer (Atago ATC-1E model). Titratable acidity (TA) was determined by titrating of 10 ml of juice with 0.1 N NaOH to an endpoint of pH 8.1 and expressed as g citric acid/100 ml fruit juice. Ratio was calculated by the relation TSS: TA.

Experimental design and data analysis

The experiment followed a complete randomized design with five replications of each treatment. Vegetative characteristics, yield data for each year, cumulative yield, yield efficiency, alternate bearing index, and fruit quality parameters were exposed to the analysis of variance using GLM procedure of SAS software (SAS Institute Inc., North Carolina, and USA). Mean separations were carried out by a Tukey test and assessed at the 5% significance level.

RESULTS and DISCUSSION

Plant growth

The rootstock significantly affected canopy height (CH), diameter (CD) and volume (CV), and trunk cross-sectional area (TCSA) but not scion to stock ratio of 'Okitsu' Satsuma trees in the 13th year after planting (YAP). In addition, plant growth of 'Clausellina' Satsuma trees was not significantly different according to rootstocks, except for CV and TCSA. The larger trees of 'Clausellina' Satsuma were those on Carrizo citrange although canopy growth of 'Okitsu' Satsuma trees on Carrizo and Troyer citranges were alike. CV of 'Okitsu' and 'Clausellina' Satsuma trees on Carrizo citrange were nearly 67% and 15% larger, respectively, than those on sour orange (Table 1). The results in harmony with Carrizo citrange rootstock provided higher canopy height and diameter than other rootstocks on 'Nova' mandarin (Demirkeser et al., 2009). On the other hand, sour orange induced higher canopy volume in 'Nova' tangelo (Georgiou, 2000) and 'Clementine' (Georgiou, 2002; Tsakelidou et al., 2002) than those budded on Carrizo citrange. However, Gonzalez-Velez et al. (2002) pointed that canopy growth of 'Orlando' tangelo trees was not influenced by the rootstocks. The features of rootstocks should be considered to decide distance on row and space between rows in establishing the orchard. The growth and development of plant were affected by various factors, such as, rootstock, genotype, ecological conditions, cultivation techniques etc. (Georgiou and Gregoriou, 1999).

At 13 year-of-age, rootstocks have significant effect on the TCSS, but this characteristic of trees changed according to scion-rootstock combination. The TCSA of trees on Troyer citrange was found the highest in 'Okitsu', and the smallest in 'Clausellina'. In addition, the TCSA of both 'Okitsu' and 'Clausellina' Satsuma trees on Carrizo citrange were importantly higher than those on sour orange (Table 1). TCSA of 'Clementine' mandarin and 'Valencia' orange trees on Carrizo citrange were discovered lower than those on sour orange by Georgiou (2002; 2004), on the other hand the tress on Carrizo citrange had similar TCSA those on sour orange in 'Fremont' mandarin (Demirkeser et al., 2011), 'Silverhill (22-9)' Satsuma (Yildiz et al., 2012), and 'Rohde Red Valencia' and 'Valencia Late' oranges (Yildiz et al., 2013).

Table 1. Effects of different rootstocks on some vegetative characteristics of 'Okitsu' and 'Clausellina' Satsuma mandarins (in the 13th YAP)

Rootstocks	Canopy height (m)	Canopy diameter (m)	Canopy volume (m^3)	Trunk cross-sectional area (cm^2)	Scion/stock ratio(3)
Okitsu Satsuma					
Sour orange	1.58b(1)	2.84b	5.75b	86.34b	0.92
Carrizo citrange	1.90a	3.36a	9.62a	140.02a	0.90
Troyer citrange	1.97a	3.25a	9.49a	156.03a	0.90
HSD (5%)	0.21	0.28	1.75	32.14	NS
Clausellina Satsuma					
Sour orange	1.59	2.40	4.22b	92.30b	0.94
Carrizo citrange	1.61	2.58	4.85a	113.16a	0.93
Troyer citrange	1.45	2.41	3.78b	85.96b	0.90
HSD (5%)	NS(2)	NS	0.43	19.21	NS

(1): Means with different letters in each column are significantly at p≤0.05 (Tukey test)
(2): NS: Non-significant.
(3): Ratio of scion trunk circumfrence to rootstock trunk circumfrence.

The ratio between scion and rootstock trunk girth is used as a scion/rootstock affinity indicator, whereas values close to 1 are related with very good affinity (Bisio et al., 2000). Most favorable rootstocks for 'Okitsu' and 'Clausellina' were sour orange although rootstock influence on scion: stock ratio had statistically similar

values (Table 1). Similar results were taken from other mandarin cultivars by Hassan et al. (2000), Georgiou (2002), Bassal (2009) and Yildiz et al. (2012) mentioning the highest scion/stock trunk girth ratio was on sour orange. Nevertheless, there is no the graft incompatibility between satsuma varieties and poncirus hybrids (Kafa and Canihos, 2010).

Yield

The fruit yield was generally influenced by the rootstocks for both scion cultivars. The yield traits differed based on years. However, the yield trends caused by rootstocks were consistent. 'Okitsu' Satsuma trees on Carrizo and Troyer citranges and 'Clausellina' Satsuma trees on Carrizo citrange had higher yield than the others. The yield of 'Okitsu' and 'Clausellina' Satsuma trees on Carrizo citrange were higher about 43% and 16% more than those on sour orange, respectively (Table 2). This finding was in agreement with others reporting the positive effect of Carrizo citrange on the yield of 'Owari' (Tuzcu et al., 1998) and 'Okitsu' (Gallash et al., 2005, Kaplankiran et al., 2005) Satsuma cultivars. However, higher cumulative yield was confirmed for 'Okitsu' Satsuma trees on Troyer citrange when compared with plants on sour orange. Although trees budded on Troyer citrange were not significantly different from those on sour orange for 'Clausellina' Satsuma trees in this variable, as the amount of yield of trees on Troyer citrange had lower cumulative fruit yield than those on the sour orange (Table 2). Our yield results are in harmony with those of Georgiou (2000) on 'Nova' tangelo, Georgiou (2002) on 'Clementine', and Demirkeser et al. (2009) on 'Robinson' mandarin trees budded on different rootstocks, reporting that the yield on Troyer citrange was lower than those budded on sour orange and Carrizo citrange, but no differences were determined in the cumulative yield of 'Murcott' (Figueiredo et al., 2001; 2006), 'Sunburst' (Filho et al., 2007), 'Fremont' (Espinoza-Nunez et al., 2007) and 'Swatow', 'Ellendale', 'Fortune' and 'Nova' mandarins (Stuchi et al., 2008) on different rootstocks. As shown in research studies in literature, yield/tree changed according to rootstock-scion combination and different ecological conditions.

To show the effectiveness of the rootstock on productivity of trees in relation to tree size, the yield per canopy volume was measured. Effects of rootstocks on yield efficiency were found to be statistically significant for both 'Okitsu' and 'Clausellina' cultivars. 'Okitsu' Satsuma trees on sour orange and 'Clausellina' Satsuma trees on Troyer citrange had significant higher yield efficiency than trees on the other rootstocks. According to average of the rootstocks, 'Clausellina' Satsuma trees, with lower canopy volumes had higher yield efficiency than 'Okitsu' Satsuma trees. Yield efficiency of 'Okitsu' Satsuma trees on sour orange was almost 61% and 64% greater than those on Carrizo and Troyer citranges, respectively (Table 2). Low yield efficiency was perhaps resulted from the bigger canopy size induced by rootstocks. Sour orange increased yield efficiency for 'Clementine' in Greece (Tsakelidou et al., 2002) and for 'Nova' in Turkey (Demirkeser et al., 2009). Sour orange also induced low yield efficiency for 'Clementine' mandarin in Cyprus (Georgiou, 2002) in comparison to Carrizo and Troyer citranges. On the other hand, Demirkeser et al. (2009) resulted that yield efficiency of 'Robinson' mandarin trees was not impressed by the rootstocks.

Table 2. Annual and cumulative yield and yield efficiency (in the 13th YAP) of Okitsu' and 'Clausellina' Satsuma mandarins on different rootstocks

Rootstocks	Yield (kg per tree)						Yield efficiency (kg/m^3)	ABI[3] (%)
	Year after planting (YAP)					Cumulative yield		
	9th	10th	11th	12th	13th			
Okitsu Satsuma								
Sour orange	53.75c[1]	68.70	70.88b	150.00b	111.52	454.8b	19.83a	0.13b
Carrizo citran.	130.80a	78.25	107.12a	216.04a	116.79	649.0a	12.29b	0.21a
Troyer citran.	93.33b	71.30	110.84a	227.71a	112.12	615.3a	12.09b	0.21a
HSD (5%)	24.09	NS[2]	26.14	31.06	NS	84.2	2.70	0.04
Clausellina Satsuma								
Sour orange	40.55b	38.09b	94.29a	136.08a	112.13	421.1b	26.85b	0.15a
Carrizo citran.	63.82a	50.20a	103.77a	148.96a	120.38	487.1a	25.16b	0.15a
Troyer citran.	46.20b	43.77ab	70.24b	107.39b	115.52	383.1b	30.75a	0.10b
HSD (5%)	12.82	8.08	22.98	19.52	NS	52.6	3.50	0.04

(1): Means with different letters in each column are significantly at $p \leq 0.05$ (Tukey test)
(2): NS: Non-significant.
(3): ABI: Alternate bearing index.

Alternate bearing index (ABI) was impacted by the rootstocks for both scion cultivars. 'Okitsu' Satsuma trees on sour orange and 'Clausellina' Satsuma tress on Troyer citrange had lower ABI than other rootstock-scion combination. According to average of the rootstocks, 'Okitsu' Satsuma trees had higher ABI than 'Clausellina' Satsuma trees (Table 2). Effect of the rootstocks on the ABI was verified in 'Okitsu' Satsuma in the subtropical region of Brazil (Cantuarias-Aviles et al., 2010). Similar results were recorded in 'Marisol' Clementine on 4 rootstocks (Bassal, 2009). This result is different from the previous study having reported no rootstock effects on the ABI of mandarins (Georgiou, 2000; Smith et al., 2004; Filho et al., 2007). With cultural practices, the ABI can be decreased with the control of the crop load during the 'on' years, by thinning fruit, girdling branch, applying plant growth regulators, and early harvest (Sposito et al., 1998). During the "off" years, the flowering may be raised by applying foliar urea (El-Otmani et al., 2004).

Fruit quality

According to 5 years average, fruit weight, juice content and TA concentration for 'Okitsu' Satsuma and fruit weight and diameter, and TSS:TA ratio for 'Clausellina' Satsuma were affected by the rootstocks. Fruit weight was higher in fruits of both 'Okitsu' and 'Clausellina' mandarin trees budded on sour orange than trees on the other rootstocks (Table 3). These results resemble to the ones in previous study (Bassal, 2009) where fruit weight of 'Marisol' mandarin on sour orange was higher than those budded different rootstocks. However, Figueiredo et al. (2006) on 'Murcott', Filho et al. (2007) on 'Fallglo' and 'Sunburst', Stuchi et al. (2008) on 'Swatow', 'Fortune' and 'Nova' and Demirkeser et al. (2009) on 'Robinson' mandarin noticed the effects of the rootstocks on fruit weight were unimportant. There is a negative relationship between the number of fruit and the size of fruit in citrus. However, in this paper, the differences in fruit weight among trees on different rootstocks weren't related with crop load.

Fruit shape index, rind thickness and TSS of both Satsuma cultivars weren't affected by the rootstocks (Table 3). Similar results were reported by Tsakelidou et al. (2002) on 'Clementine', Bassal (2009) on 'Marisol', and Demirkeser et al. (2009) on 'Nova' and 'Robinson' mandarins, stating that rind thickness was not significantly different among rootstocks. Similarly, Demirkeser et al. (2009) stated TSS of 'Nova' and 'Robinson' mandarin trees weren't influenced by the rootstocks. By contrast, Legua et al. (2014) on 'Clementine' found that the there were small differences between root-stocks with respect to TSS variables.

Fruit of 'Clausellina' Satsuma trees had lower juice content than those of 'Okitsu' Satsuma trees. 'Okitsu' Satsuma trees on Carrizo citrange had higher juice content than those budded on the other rootstocks, while the rootstocks hadn't important impacts on juice content of 'Clausellina' Satsuma (Table 3). Our results supplied from 'Clausellina' Satsuma are in agreement with those of Fallahi and Rodney (1992) on 'Fairchild', Figueiredo et al. (2006) on 'Murcott', Filho et al. (2007) on 'Fallglo' and 'Sunburst', Stuchi et al. (2008) on 'Swatow', 'Fortune' and 'Nova', Bassal (2009) on 'Marisol', Demirkeser et al. (2009) on 'Nova' and 'Robinson', and Gonzatto et al. (2011) on 'Oneco' mandarin, reporting juice content wasn't influenced by the rootstock. Our juice content of 'Okitsu' Satsuma results provided from this study was higher than the ones of 'Okitsu' Satsuma by Cantuarias-Aviles et al. (2010), reporting that fruits on 12 rootstocks had juice content between 39.5% and 47.5%.

Table 3. The effects of different rootstocks on fruit quality of 'Okitsu' and 'Clausellina' Satsuma mandarins (Average 9th-13th YAP)

Rootstocks	Fruit weight (g)	Fruit diameter (mm)	Fruit shape index	Rind thickness (mm)	Juice content (%)	TSS (%)	TA (%)	TSS:TA ratio
Okitsu Satsuma								
Sour orange	134.14a(1)	66.17	1.26	2.73	52.92ab	9.42	1.11a	8.62
Carrizo citran.	131.43ab	65.17	1.28	2.98	53.68a	9.24	1.05b	8.87
Troyer citran.	125.49b	64.61	1.28	2.75	52.59b	9.15	1.05b	8.83
HSD (5%)	6.41	NS(2)	NS	NS	0.78	NS	0.02	NS
Clausellina Satsuma								
Sour orange	116.54a	62.91a	1.28	3.08	50.35	9.25	1.04	9.03ab
Carrizo citran.	104.73b	60.87ab	1.31	3.12	49.55	9.32	1.01	9.39a
Troyer citran.	107.56b	60.18b	1.31	2.93	49.79	9.11	1.05	8.79b
HSD (5%)	8.54	2.09	NS	NS	NS	NS	NS	0.47

(1): Means with different letters in each column are significantly at p≤0.05 (Tukey test)

(2): NS: Non-significant.

Although TA concentration wasn't meaningfully differed by the rootstocks on 'Clausellina' Satsuma, it was higher in fruits of 'Okitsu' Satsuma trees on sour orange than those grafted on the other rootstocks.

The TSS:TA ratio which is the most widely used method to estimate citrus maturity level is an important parameter related to quality characteristic of Citrus fruits (Legua et al., 2014). High values of TSS:TA ratio was confirmed in fruits of 'Clausellina' Satsuma trees on Carrizo citrange, while TSS: TA ratio was not affected by the rootstock in 'Okitsu' Satsuna tress (Table 3). Similar results were also found for 'Nova' tangelo budded on 11 rootstocks by Georgiou (2002), reporting that mandarin trees on Carrizo citrange was higher TTS:TA ratio than those on sour orange and Troyer citrange. Figueiredo et al. (2006) on 'Murcott', Stuchi et al (2008) on 'Swatow', 'Ellendale' and 'Fortune', and Demirkeser et al. (2009) on 'Robinson' and 'Nova' mandarins observed impacts of the rootstocks on TSS:TA ratio weren't meaningful. On the other hand, our results showed that TSS:TA ratio of both 'Okitsu' and 'Clausellina' Satsuma cultivars registered lower ratio than the findings (10.5-12.5) of Cantuarias-Aviles et al. (2010) on 'Okitsu' Satsuma. Fruit quality of citrus in this study varied according to the rootstocks used and rootstock-scion combination. These differences are attributable to climatic conditions (illumination, temperature differences between day and night, etc.) and cultural practices (pruning, irrigation, fertilization etc.).

CONCLUSION

'Okitsu' Satsuma to replace 'Owari' Satsuma is an applicable alternative to spread commercial purposes because of its high yield efficiency, high fruit quality and good fruit external appearance. 'Clausellina' Satsuma should also replace 'Owari' Satsuma because of its higher quality fruits and the ability of earlier maturity for fresh fruit market. There are advantages to the early shipment and sale of early mandarins. But, early varieties in the Dörtyol region will delay the fruit peel coloration because of unstable weather conditions, including high temperatures in early fall. Therefore, exporting of Satsuma fruits requires the enhancement of peel color, which may be achieved by degreening treatments.

Carrizo and Troyer citranges for the 'Okitsu' Satsuma, and Troyer citrange for 'Clausellina' Satsuma are capable of being a suitable alternative rootstock to sour orange. Carrizo citrange rootstock can be used to eastern Mediterranean soils where calcium (free lime) levels are high. Carrizo citrange rootstock has good tolerance to high lime content than Troyer citrange.

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