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LEAF MINERAL COMPOSITION OF 'NOVA', 'ROBINSON' AND 'FREMONT' MANDARIN CULTIVARS ON DIFFERENT ROOTSTOCKS

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□ *Rootstock selection has a critical importance for mineral nutrition of budded cultivars. This study was conducted at the experimental farm of Mustafa Kemal University, Dörtyol, Turkey. The aim of this study was to investigate the effect of sour orange, Troyer and Carrizo citrange rootstocks on the leaf nutrient contents of 'Nova', 'Robinson', and 'Fremont' mandarin cultivars in the 2004 and 2005 growing seasons. Carrizo citrange was examined for nitrogen (N), potassium (K), magnesium (Mg), sodium (Na), and manganese (Mn); Troyer citrange for iron (Fe); and sour orange for calcium (Ca) and zinc (Zn) were superior on the others. Nitrogen, phosphorus (P) and Mg levels of mandarin leaf budded on sour orange were under or just above the deficiency threshold. Potassium, Mn, and Zn content of 'Robinson'; P, Ca and Fe content of 'Fremont'; and Cu content of 'Nova' were statistically higher. Therefore, it can be concluded that Carrizo rootstock may be suggested for the region and regions with similar ecological conditions.*

Keywords: mandarin, rootstock, nutrient uptake

INTRODUCTION

Turkey is one of the major citrus-producing countries of the northern Mediterranean region with suitable climate and other ecological conditions. There was more than a twofold increase in citrus production from 1,492,000 tons in 1991 to 3,225,017 tonnes total production of various type of citrus in 2006 (FAO, 2006) with increasing commercial importance. Mandarin has the second largest share for citrus production with a total of 791,225 tons in Turkey. The Mediterranean region, especially the eastern part, has the

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largest production capacity, and Hatay province alone produces as much as 28.05% of total mandarin production in Turkey (Anonymous, 2006).

Since the majority of old mandarin orchards had used 'Ovari' cultivar up to the 1990s there is a marketing problem and excessive production related to low price levels. In addition, insufficient warehouse capacity for the storage of the fruits increases the severity of the problem for the farmers. Thus, expanding the production season towards meeting consumers' and producers' demands by using early and late maturing cultivars can help solve the problem (Demirkeser et al., 2003; Kaplankıran et al., 2005). To overcome the problem many new mandarin cultivars were introduced to farmers. 'Nova' and 'Robinson' mandarins, hybrids between Clementine and 'Orlando' tangelo, are preferred in the European market and elsewhere due to large and eye-catching fruit appearance with suitability for transportation and storage. These cultivars are grown in Mediterranean countries such as Spain and Israel and are rapidly expanding in the eastern Mediterranean region of Turkey in the last decade (Saunt, 1990; Tuzcu, 1990; Anonymous, 2000).

A suitable rootstock should be used to overcome limitations in citrus cultivation (i.e., soil, climate, disease, pests) and to meet both consumers and producers demands (i.e., fertility, shorter juvenility, fruit quality, low price) (Tuzcu, 1978; Davies and Albrigo, 1994). Adaptation ability of any rootstock to the differing ecological conditions and reflection of these abilities to horticultural characteristics of the scion cultivar, such as tree growth, yield, and fruit quality could be different (Fallahi et al., 1991; Akgül and Tuzcu, 1993; Gregoriou and Economides, 1993; Tuzcu et al., 1998; Bowman, 1998; Georgiou, 2000; Noda et al., 2001; Stenzel et al., 2003; Demirkeser et al., 2003; Romero et al., 2006; Filho et al., 2007). Since the rootstock forms the root system of the three, rootstocks can strongly influence water and nutrient elements uptake and their translocation. The uptake and transport of nutrient elements taking place critical role in physiological and biochemical processes, fertility and yield quality are different for each rootstock-scion combination (Iyengar et al., 1982; Fallahi and Rodney, 1992; Taylor and Dimsey, 1993; Kaplankıran et al., 1995, 1996; Zekri, 2000; Moeen et al., 2001; Tsakelidou et al., 2002; Georgiou, 2002; Smith et al., 2004; Marathe et al., 2004, 2006).

Nutrient uptake and translocation are affected by several factors including soil characteristics, root and tree vigor, and climatic conditions. On the other hand, abundance of macro and micro elements varies considerably with soil type and citrus-growing region worldwide. Rootstocks differ not only morphologically but also physiologically with regard to water and nutrient uptake even under similar environmental conditions (Davies and Albrigo, 1994). Thus it is necessary to use rootstocks with better ability to uptake essential nutrient elements in order to obtain economically feasible growth performance and yield and to develop more economic and environmentally friendly fertilization program.

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Since leaf analysis is generally preferred to soil analysis for evaluating the nutritional status of an orchard, yearly programmed leaf analysis could be useful to assess and select best possible rootstocks for any specific ecological condition. Therefore, the aim of this study was to compare the suitability of sour orange, Troyer and Carrizo citranges rootstocks for 'Nova', 'Robinson', and 'Fremont' mandarin cultivation in the region by means of leaf nutrient levels.

MATERIAL AND METHODS

The experiment was set up in the Mustafa Kemal University experimental farm in Dörtyol, Hatay, Turkey (36° 09′ E, 36° 51′ N; 9 m above the sea level) in randomized complete design (RCD) with five replicates. 'Nova', 'Fremont', and 'Robinson' mandarin cultivars were budded on the sour orange (*Citrus aurantium* L.), Troyer and Carrizo citranges (*Poncirus trifoliata* Raf. x *Citrus sinensis* Osb. var. "Troyer" and "Carrizo"). One year old budded trees were planted with 7 × 7 m spacing in 1998. Seeds of rootstocks and buds of the mandarins were supplied from Cukurova University.

The climate of the Dörtyol is a typical Mediterranean climate with hot and dry summer period with minimal rainfall and mild and rainy winter–spring seasons. Measured maximum temperature average in 2004 and 2005 were 30.3°C and 24.6°C whereas the minimum temperature averages were 8.6°C and 14.2°C. The averaged temperatures were 19.1°C and 18.8°C. Total annual rainfall was 676.8 and 1030 mm for 2004 and 2005, respectively.

Soil samples were taken to describe the characteristics of soils from 0–30, 30–60, and 60–90 cm depth. Air dried soil samples were gently crushed and passed through a 2 mm sieve. Particle size distribution was determined by the hydrometer method (Gee and Bauder, 1986). Soil chemical properties were determined following standard procedures: both pH and electrical conductivity in 1: 2.5 soil: water suspension, calcium carbonate ($CaCO_3$) equivalent by a manometric method. The measured characteristics of soil profile up to 90 cm were given in Table 1.

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

TABLE 1 Some chemical and physical characteristics of soil

	Sand	Silt	Clay	$CaCO_3$	pH	EC (mS cm^{-1})
Depth (cm)	g kg^{-1}				1:2.5 soil: water suspension	
0–30	694	245	61	61.8	7.80	218
30–60	646	271	83	63.5	7.98	132
60–90	668	270	62	114	8.25	114

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and pest control were made according to "integrated pest management method."

In order to assess nutritional status of mandarins, leaf samples were collected from nonfruiting shoots, fully expanded four to seven month old leaves and transferred to the laboratory in the ice box (Chapman, 1960). Then samples were freed from the contaminants by washing surface-active detergent solution, tap water and finally by rinsing with distilled water. Samples were dried at 70°C until constant weight and homogenized by reducing the particle size <0.5 mm. Powdered samples were digested with nitric acid (HNO_3)/perchloric acid ($HClO_4$) mixture (3:1 v/v) (Kacar, 1972). The concentrations of calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), copper (Cu), manganese (Mn), and zinc (Zn) in digest were determined by means of Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES, Varian, Liberty Series II; Varian Inc., Palo Alto, CA, USA). Phosphorus content was spectrophotometrically determined by Barton reagent (Barton, 1948). Semi-micro Kjeldahl method was used to determine N content of samples (Lees, 1971).

The data were subjected to ANOVA and mean separation were made by Least Squared Difference (LSD) test at $P = 0.05$. Statistical calculations were made by using SAS package (SAS Institute, Cary, NC, USA).

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RESULTS AND DISCUSSION

Leaf nutrient levels were significantly affected by growing season but Ca (Tables 2 and 3). The yearly averages of the elements were well in the optimum ranges (Marchal, 1987). In general, rootstock and rootstock-scion combinations significantly affected the nutrient level of 10 elements. Cultivar significantly affected leaf levels of eight out of 10 elements but Mg and Na contents of the cultivars were statistically similar (Tables 2 and 3).

Leaf nutrient levels can change in different growing years depending on the environmental differences, yield, root and shoot vigor and agricultural practices (Davies and Albrigo, 1994; Kaplankıran and Tuzcu, 1993). The averages in this study were very close to each other but the difference was somehow significant.

Nitrogen is one of the most critical elements in determining yield, fruit quality and tree vigor. Leaf nitrogen content of mandarin cultivars budded on different rootstocks was significantly different. Carrizo citrange performed better than the other two rootstocks in N uptake. Sour orange, however, yielded minimum N level just below the deficiency threshold. This can be attributed to root structure of the sour orange that majority of nutritional roots are in the deeper horizon (Tuzcu et al., 1997), but soil nitrogen is usually present at the upper horizon and bound to soil organic matter; despite coarse soil texture can enable, to some extent, leach down fertilizer

TABLE 2 Mean and mean comparisons for several macro nutrient elements in some mandarin cultivars grown on three rootstocks 2004 and 2005

Source	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Year					
2004	2.31 b	0.14 b	1.15 b	5.10	0.34 b
2005	2.36 a	0.15 a	1.20 a	5.00	0.35 a
$LSD_{0.05}$	0.029	0.005	0.024	n.s.	0.006
Rootstocks					
Sour orange	2.18 c	0.13 b	1.11 c	5.60 a	0.31 c
Carrizo citrange	2.47 a	0.15 a	1.26 a	4.70 c	0.38 a
Troyer citrange	2.37 b	0.16 a	1.16 b	4.90 b	0.36 b
$LSD_{0.05}$	0.036	0.006	0.029	0.077	0.007
Cultivar					
Fremont	2.35 a	0.15 a	1.12 c	5.30 a	0.34
Nova	2.31 b	0.14 b	1.18 b	5.00 b	0.35
Robinson	2.37 a	0.14 b	1.23 a	4.90 b	0.35
$LSD_{0.05}$	0.036	0.006	0.029	0.077	n.s.
Interaction					
Sour orange					
Fremont	2.24 c	0.13 cd	1.00 d	5.76 a	0.31 c
Nova	2.08 d	0.12 d	1.14 bc	5.59 a	0.30 c
Robinson	2.22 c	0.13 cd	1.19 a–c	5.53 a	0.30 c
Carrizo citrange					
Fremont	2.45 ab	0.17 a	1.25 ab	4.95 bc	0.36 ab
Nova	2.47 a	0.14 b–d	1.24 ab	4.59 d	0.39 a
Robinson	2.48 a	0.15 a–c	1.29 a	4.57 d	0.39 a
Troyer citrange					
Fremont	2.36 b	0.16 ab	1.11 cd	5.14 b	0.35 b
Nova	2.37 b	0.16 ab	1.17 bc	4.78 cd	0.37 ab
Robinson	2.39 ab	0.16 ab	1.21 a–c	4.69 cd	0.37 ab
$LSD_{0.05}$	0.10	0.022	0.11	0.28	0.028
Mean	2.34	0.140	1.18	5.10	0.35
Optimum range*	2.20–2.70	0.12–0.18	1.00–1.70	3.00–6.00	0.30–0.60

*Accorging to Marchal (1987); ns: not significant.
Different letters within columns denote significant difference.

nitrogen to deeper horizon (Davies and Albrigo, 1994; Alva et al., 2006). Similar to this study Carrizo and Troyer citranges were reported to be superior over sour orange in N uptake for example Fallahi and Rodney (1992) for Fairchild, Kaplankıran et al. (1995) for Clementine and 'Fremont', Georgiou (2000) for 'Nova', Tsakelidou et al. (2002) for Clementine, and Marathe et al. (2004) for Nagpur mandarin. Wutscher (1989) listed the sour orange in the rootstocks with low nitrogen uptake ability. In contrast, Kaplankıran et al. (1996) and Georgiou (2002) reported no effect of rootstock on leaf N level.

Rootstock-scion relation had also a significant effect on N level of leaf. All of the used cultivars yielded better N uptake on Carrizo citrange. In contrast, sour orange-cultivar combinations had minimum N contents, even deficient for 'Nova' budded on sour orange.

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TABLE 3 Mean and mean comparisons for several micro nutrient elements in some mandarin cultivars grown on three rootstocks 2004 and 2005

Source	Na (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
Year					
2004	0.109 b	82.5 b	70.8 b	28.0 b	12.0 b
2005	0.118 a	85.3 a	74.3 a	29.3 a	12.8 a
$LSD_{0.05}$	0.001	2.062	2.445	1.078	0.553
Rootstocks					
Sour orange	0.097 c	79.5 c	67.5 c	31.3 a	10.7 b
Carrizo citrange	0.126 a	84.2 b	77.6 a	27.6 b	13.2 a
Troyer citrange	0.118 b	87.9 a	72.6 b	27.0 b	13.2 a
$LSD_{0.05}$	0.005	2.53	2.99	1.32	0.68
Cultivar					
Fremont	0.112	88.7 a	71.0 b	26.2 c	9.9 b
Nova	0.114	84.2 b	70.9 b	27.7 b	13.8 a
Robinson	0.115	78.8 c	75.9 a	32.1 a	13.4 a
$LSD_{0.05}$	n.s.	2.53	2.99	1.32	0.68
Interaction					
Sour orange					
Fremont	0.096 d	84.2 a–c	63.0 d	28.1 b–e	8.2 d
Nova	0.097 d	81.4 b–d	66.5 cd	30.7 a–c	12.0 bc
Robinson	0.098 cd	73.0 d	73.0 bc	35.2 a	11.9 bc
Carrizo citrange					
Fremont	0.117 a–c	89.8 ab	83.5 a	26.2 c–e	10.4 cd
Nova	0.127 ab	84.9 a–c	71.9 bc	25.6 de	14.8 a
Robinson	0.133 a	78.0 cd	77.5 ab	31.1 ab	14.5 a
Troyer citrange					
Fremont	0.122 ab	92.0 a	66.4 cd	24.4 e	11.2 c
Nova	0.118 ab	86.3 a–c	74.2 bc	26.7 b–e	14.6 a
Robinson	0.113 b–d	85.4 a–c	77.2 ab	30.0 b–d	13.7 ab
$LSD_{0.05}$	0.019	9.89	8.29	4.73	2.42
Mean	0.113	83.9	72.6	28.7	12.4
Optimum range*	0.01–0.15	60–150	25–100	25–100	5.10–15.0

*Accorging to Marchal, 1987; ns: not significant.
Different letters within columns denote significant difference.

Leaf P contents of cultivars budded on Carrizo and Troyer citranges yielded similar high values while cultivars on sour orange uptake significantly smaller P just above the deficiency threshold (Table 2). 'Nova' and 'Robinson', which are both hybrid of Clementine and Tangelo, showed the same P level which was significantly smaller than that of 'Fremont'. Maximum P uptake was observed for 'Fremont'/Carrizo combination and the lowest values for cultivars/sour orange combinations. Many researchers have pointed out that rootstocks significantly differs leaf P content of cultivars (Kaplankıran et al., 1996; Georgiou, 2000; Tsakelidou et al., 2002; Smith et al., 2004). Carrizo and Troyer were superior over sour orange in P uptake because of the nature of the P in soil profile and distribution of nutritional roots. Plant available soil P is more abundant in the upper horizon especially in 0–30 cm layer, thus the density of nutritional roots in the surface horizon is critical

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for P nutrition. By considering this criterion Carrizo and Troyer citranges have much more nutritional roots in 0–30 cm depth in comparison to sour orange (Davis and Albrigo, 1994; Tuzcu et al., 1997).

Scion/rootstock relation between Carrizo and 'Fremont' in comparison to other mandarin cultivars was likely to be better for P translocation from root to shoots. However, Troyer well adapted all of the budded cultivars towards better P uptake and translocation.

The rootstocks had significantly influenced the leaf K content of mandarins (Table 2) despite leaf K contents was in the optimum range (1.00–1.70%). Carrizo citrange was superior over the other rootstocks in K uptake and translocation to leaves. Nutrient translocation to shoots and leaves are an indication of well scion/rootstock relation that Carrizo was the best of rootstocks used. 'Fremont'/sour orange combination showed K content around deficiency threshold. Researchers have reported contradictory results that rootstocks had some or no effect on K uptake (Georgiou 2002; Smith et al., 2004); however, others have reported significant effects even causing K deficiency for certain scion/rootstock combinations (Kaplankıran et al., 1995, 1996; Georgiou, 2000; Tsakelidou et al., 2002). Many researchers have reported that Carrizo citrange as rootstocks, as in this study, enhance K uptake of budded cultivars.

Sour orange increased leaf Ca content of cultivars (Table 2). The reason for such behaviour could be root distribution of sour orange and $CaCO_3$ content of soil in the profile (Table 1). Nutritional roots of sour orange develop in the deeper horizons (Davis and Albrigo, 1994; Tuzcu et al., 1997) that have comparatively higher carbonate content. Thus, more Ca can be translocated to leaves of mandarin cultivars budded onto sour orange. Calcium uptake by the other two rootstocks was relatively less but it was well within the optimum range (3.00–6.0%) as reported by Kaplankıran et al. (1995, 1996), Georgiou (2000, 2002), Tsakelidou et al. (2002), and Smith et al. (2004).

Magnesium uptake by the mandarin cultivars was significantly influenced by scion/rootstock combinations. Cultivars budded onto sour orange showed Mg levels (0.30–0.31%) around the deficiency threshold (Table 2). 'Nova' and 'Robinson' mandarins showed similarly high Mg uptake performances by Carrizo and Troyer citranges in comparison to 'Fremont' mandarin. The results of this study were in agreement to those of Kaplankıran et al. (1995, 1996), Georgiou (2000, 2002), Tsakelidou et al. (2002), and Smith et al. (2004) who reported a superiority of Carrizo citrange in Mg uptake.

Sodium hazards are critical in arid regions soils. Therefore scion/rootstock combinations limiting Na uptake is preferable in such environment. All combinations studied showed a Na level in the optimum range, but Carrizo and Troyer citranges had comparatively higher values towards toxicity thresholds (Table 3). Wutscher (1989) reported that sour orange induced low levels of Na, as in this study. Carrizo citrange induced highest

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level of Na uptake for 'Nova' and 'Robinson' mandarins. Similar to our results, Kaplankıran et al. (1995) reported higher leaf Na levels for 'Fremont' mandarin when budded onto Carrizo and Troyer citranges. Kaplankıran et al. (1995, 1996), Georgiou (2000; 2002) found the Na levels in the optimum range (0.01–0.15%) for different rootstocks; however, Smith et al. (2004) reported irrigation water induced very high Na levels for Ellendale mandarin.

Leaf Fe content of mandarin cultivars budded on different rootstocks was well in the optimum range (Table 3). However, their Fe uptake performances are in descending order as Troyer (87.9 mg kg^{-1}) > Carrizo (84.2 mg kg^{-1}) > sour orange (79.5 mg kg^{-1}). 'Fremont' cultivar had highest Fe levels for all rootstock combinations. In contrast to our findings, Kaplankıran et al. (1996) and Georgiou (2000, 2002) reported no effects of rootstocks on Fe uptake, whereas Pestana et al. (2005) reported that Troyer citrange was resistant to Fe deficiency. Carrizo and Troyer citranges induced high leaf Fe levels in comparison to sour orange (Kaplankıran et al., 1995).

Carrizo citrange induced high levels of Mn on average (Table 3) and showed better affinity to 'Fremont' mandarin. By considering Mn uptake, affinity of 'Nova' to Troyer, and 'Robinson' to both, Carrizo and Troyer citranges were better than the other combinations. Similarly Kaplankıran et al. (1995) and Georgiou (2002) reported Carrizo citrange induced high Mn levels for 'Fremont' and Clementine mandarins, respectively. In contrast, Fallahi and Rodney (1992) found low Mn levels with 'Carrizo' and suggested this rootstock to acid soils high in available Mn.

'Nova' and 'Fremont' mandarins budded on Carrizo and Troyer citranges had low levels of Zn, below or just above the deficiency threshold (Table 3). Sour orange performed better in Zn uptake and translocation to leaves for the cultivars utilized. Georgiou (2000, 2002) and Tsakelidou et al. (2002) have also reported sour orange induced enrichment in leaf Zn level. In general, Zn levels of all combinations used in this study were about the deficiency threshold. The reason for such low level of Zn could be attributed to low availability of Zn in the region's soils (Tuzcu et al., 1981). On the other hand, high levels of carbonate minerals along with the alkaline pH further reduced the availability of soil Zn (Marschner, 1995).

As in this study, Cu levels of leaves were generally in the optimum range (Table 3) because of the usage of Cu containing fungicides in the citrus orchards (Kaplankıran et al., 1995, 1996; Georgiou, 2000, 2002; Smith et al., 2004). Despite coarse soil texture that can induce Cu deficiency, Cu contents of leaves were in the optimum range. Thus, the true effect of scion/rootstock interactions were shadowed; however, Carrizo and Troyer citranges were superior to sour orange in Cu uptake. The low level of Cu for sour orange may be related to the deep and moderately branched root systems produced by sour orange, which does not enable it to uptake sprayed Cu on soil to a lesser extent. Similarly, Kaplankıran et al. (1996) and Georgiou (2000)

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suggested Carrizo citrange whereas Georgiou (2002) Troyer citrange for a better rootstock induced Cu nutrition.

A better yield and fruit quality of scion /rootstock combinations with the high ability to uptake essential nutrient elements is expected. Comparatively higher amounts of the essential nutrient elements in leaves is an indication of the higher yield and yield quality which is in agreement with the results of Kaplankıran et al. (1999) who reported higher N, K, Fe, and Mn uptake ability of rootstocks enhanced fruits quality parameters.

It can be concluded that there are considerable differences in nutrient uptake ability of rootstocks. For example Carrizo citrange was performed better for N, K, Mg, Mn, and Cu uptake; Troyer citrange for P, Fe, and Cu; and sour orange for Ca and Zn. Therefore, by considering such differences in nutrient uptake, rootstock selection is as critical as cultivar selection and ecological conditions for a balanced, environmentally friendly and economically feasible fertilization program. The overall performance of Carrizo and Troyer citranges were better than sour orange in the uptake of essential nutrient elements critical for yield and yield quality. Therefore, Carrizo and Troyer citranges could be used as appropriate rootstocks for this region and regions with similar ecological conditions.

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