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Full Length Research Paper

The effects of citrus rootstocks on Valencia Late and Rhode Red Valencia oranges for some plant nutrient elements

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In citrus production, the rootstocks utilization is beneficial for solving the problems caused by soil, climates, pests and diseases as well as achieving higher productivity and quality, earlier and later fruit productions. Therefore, citrus producer almost exclusively utilizes rootstocks. The major rootstock of Turkish citrus production is sour orange while trifoliate, Troyer and Carrizo citranges are utilized as well. In this study, we determined the rootstock effects on some plant nutrient element status of Rhode Red Valencia and Valencia Late oranges budded on sour orange, Troyer and Carrizo citranges in 2004 and 2005. Our results were similar in both experimental years with few expectations. The nutrient status of the two orange cultivars tested significantly differed from K and Ca concentrations in both years. However, all cultivars mean were within the range of optimal limits except Zn. The rootstock had significantly different means for all elements tested in both years. We demonstrated that the citrus rootstocks had different abilities to utilize plant nutrient elements. For N, K, Mg, Mn and Cu, Carrizo citrange has the highest means while Troyer and sour orange have the highest concentrations for P and Fe, and Ca, Zn and Na, respectively. We recommend utilizations of Carrizo and Troyer citrange rootstocks for eastern Mediterranean region citrus production as they had higher ability to utilize many plant nutrient elements playing important roles in productivity and quality.

Key words: *Citrus sinensis*, citrus rootstocks, citrange, nutrient elements, sour orange.

INTRODUCTION

Turkey has a great potential for citrus production when its ecological and other characteristics were considered. Currently, Turkish citrus production is 3.220.450 t coming from 1,535,800 t of orange (*Citrus sinensis* (L.) Osb.), 791,255 t mandarins (*Citrus reticulate* Blanco), 710,400 t lemon (C*itrus limon* (L.) Burm.) and 180,000 t grapefruit (*Citrus paradisi* Macf.) (Anonymous, 2006). The important citrus producing regions include Mediterranean, Aegean and Black Sea regions. Located on eastern part of Mediterranean region, Hatay province has a more than 600,000 t of citrus production. About 20% of this production is from oranges. This production tabulates about 14% of Turkish orange production (Anonymous, 2006a). Recently, there has been an increase on early and late orange cultivars worldwide possibly caused from the changes in consumers habits and preferences. Changes in consumptions type were also thought to be affecting these preferences as well. Given that Valencia Late, Midknight Valencia and Rhode Red Valencia were all late maturing orange cultivars and they can be consumed both as table and processing fruits, the shares of these oranges significantly increased on the newly established orange orchards (Kaplankıran et al., 2005).

Because of the benefits on solving the problems caused by soil, climates, pests and diseases, the rootstock utilization is almost mandatory in citrus productions (Tuzcu, 1978; Davies and Albrigo, 1998). They also supply additional benefits on achieving higher productivity and quality, earlier and later fruit productions. The major rootstock of Turkish citrus production is sour orange (*Citrus aurantium* L.) while trifoliate (*Poncirus trifoliata* Raf.) and Troyer and Carrizo citranges (*P. trifoliata* Raf. x *C. sinensis* Osb. var. “Troyer” and “Carrizo”) are utilized

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as well. Although sour orange has many advantages over other rootstocks, its susceptibility to Tristeza virus have made researchers and producers to search for other alternatives (Salibe, 1973; Tuzcu, 1978; Davies and Albrigo, 1998). There has been an increase on the utilizations of Troyer and Carrizo citranges on eastern Mediterranean regions (Tuzcu et al., 1998; Kaplankıran et al., 2001).

Since the root systems of the citrus trees are developed from the rootstocks utilized, the rootstock has direct effects on water and nutrient uptake and translocations. The effects of rootstocks on several physiological and biochemical effects causing differences in plant development, productivity, fruit quality are well documented in several citrus species (Kaplankıran and Tuzcu, 1993; Protopapadakis et al., 1998; Georgiou and Gregoriou, 1999; Kaplankıran et al., 1999; Al-Jaleel and Zekri, 2003). Given that the rootstocks are diverse genotypes, they may influence the plant nutrient status of scions grafted on them. These effects may even change on differential environments. For this reason, it is important to determine the effect of rootstocks on plant nutrient status to optimize fertilization programs. This may eventually be beneficial to optimize yield and quality in citrus orchards. The objective of this study was to determine the rootstock effects on some plant nutrient element status of Rhode Red Valencia and Valencia Late oranges grafted on sour orange, Troyer and Carrizo citranges.

MATERIALS 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) in randomized complete design (RCD) with five replicates. Rhode Red Valencia and Valencia Late cultivars were budded on the sour orange, Troyer and Carrizo citranges. One year old budded trees were planted with 7 x 7 m spacing in 1998. Seeds of rootstocks and buds of the oranges were supplied from Çukurova University. Results of 2004 and 2005 were presented in this study.

Some climatical parameters of Dörtyol for 2004 and 2005 were as follows: averaged maximum temperature, 30.3 and 24.6°C; averaged minimum temperature, 8.6 and 14.2°C; averaged temperature, 19.1 and 18.8°C; and aggregated precipitation, 676.8 and 1030 mm, respectively.

The soil is coarse textured (sand, 646-693; silt, 245-270; and clay, 64.6-69.4 g kg^{-1}) 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), and rich in carbonate content (61-63 g/kg for 0-60 cm and 113.5 g/kg for 60-90 cm depth). The trees were fertilized with 500 g N/tree (2/3 of it at the end of February and 1/3 at the end of May), 300 g P/tree (in December) and 300 g K/tree (by the end of January). Disease and pest control were made according to integrated pest management method.

Old leaves, 4-7 months, were sampled from the fruitless shoots in autumn in 2004 and 2005 according to Chapman (1960). Leaf samples were decontaminated by washing detergent solution, tap water and rinsing with distilled water. Then, samples were dried at 70°C until constant weight and homogenized by particle size reduction to <0.5 mm. The powdered samples were then digested with HNO_3-$HClO_4$ mixture (3:1 v/v) (Kacar, 1972). In the extract solutions Na, K, Mg, Ca, Fe, Mn, Cu and Zn were determined by Inductively coupled plasma atomic emission spectrometer (ICP- AES, Varian Liberty Series II) and P by the Barton reagent at UV/VIS spectrometer (Shimadzu, 1208). Total N was determined by a micro-Kjeldahl procedure (Lees, 1971). The elemental contents of leaves were evaluated according to threshold values given by Marchall (1987).

The data were analyzed using the SAS program (SAS, 1990). TABULATE was used to obtain descriptive statistics and mean tables while GLM procedure was utilized to construct for analysis of variance (ANOVA) tables. The mean separations for significant main factors of rootstocks and cultivars were conducted by Least Significant Difference (LSD) methods at 0.05 significant level.

RESULTS AND DISCUSSION

The data from 2004 and 2005 were analyzed separately. In 2004, the differences between the cultivars were significant for K and Ca while the rootstocks were found to be significant for all the elements tested (Table 1). None of the cultivars x rootstocks interactions were significant. Similar results were obtained from the analyses of 2005 data. First, the differences among cultivars were significant for K and Ca. Additionally, Zn content also significantly differed in 2005. All elements significantly differed among rootstocks as well. The interactions were found to be not significant. The fact that the interactions were not significant neither of the years enabled us to perform LSD means separations for significant main effects of rootstocks and cultivars.

Regarding the differences between the two cultivars tested for the several nutri-elements, similar mean values were tabulated for most of the elements. Rhode Red Valencia always had higher numbers than Valencia Late for significantly different means. For example, in 2004 the K and Ca contents were 1.15 and 1.07%; 5.37 and 5.04%, respectively. In 2005, they had 1.20 and 1.15% and 5.28 and 4.95% K and Ca contents, respectively (Table 2). Although the significant differences were significant between two cultivars for K and Ca, the mean values were still comparable. More importantly, both values were still within the optimum range suggested by Marchall (1987). Given that other differences were not significant we can conclude that the nutrient statuses of the cultivars were similar with the exception of Zn. In 2005, Rhode Red Valencia had higher mean than Valencia Late (27.1 vs. 21.56 mg/kg). Since the low limit of the optimum value for Zn suggestion was 25 mg/kg (Marchall, 1987) the concentrations of Zn content of Valencia were found to be lower than suggested values.

The rootstocks differed for all of the elements tested in both years (Table 1). When the mean separations were compared, the most of the mean groups were similar in both years as well (Table 2). For example, the mean separations revealed for N, P, K, Ca, Mg, Na and Cu were identical. However, the values recovered for all elements from all combinations were within the optimal ranges (Marchall, 1987) except Zn. The consistent differences suggest that the rootstock differed in uptake and/or utilization of the plant nutrient elements tested in this study.

Table 1. Analysis of variance tables of several plant nutrient elements for Valencia Late and Rhode Red Valencia oranges budded on Carrizo citrange, Troyer citrange and Sour orange.

Source	df	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
2004											
Cultivar (C)	1	0.53	0.03	5.21**	82.01**	0.01	0.02	1.2	12.0	17.6	1.2
Rootstock (R)	2	11.98**	0.08*	11.58**	182.12**	1.14**	0.38**	116.1**	722.6**	15.7*	38.2**
C x R	2	0.02	0.01	0.45	2.35	0.02	0.00	26.8	0.4	5.2	0.3
Error	24	0.44	0.02	0.33	1.58	0.02	0.01	20.3	54.0	4.5	1.9
2005											
Cultivar (C)	1	0.00	0.03	2.30*	81.02**	0.00	0.02	4.0	140.8	240.8**	1.6
Rootstock (R)	2	11.50**	0.13**	9.49**	169.08**	1.22**	0.41**	258.0**	634.3**	19.6*	24.1**
C x R	2	0.04	0.01	0.31	1.26	0.00	0.00	42.4	142.4	1.7	0.2
Error	24	0.41	0.02	0.45	1.84	0.02	0.01	30.2	45.1	5.5	2.3

*,**Significant at 5 and 1%, respectively.

The mean separation patterns were similar in N, K, Mg and Cu in both years (Table 2). Carrizo citrange had the highest means, followed by Troyer citrange and sour orange. P and Fe had similar patterns where Troyer citrange consistently had higher means than sour orange. However, the differences among both citranges were significant only in one year treatment. Sour orange had higher means than Troyer citrange for Zn content in both years; and the differences among citranges were only significant for one year. Similar patterns were detected for Ca, Na and Mn where sour orange concentrations were consistently higher in both years at least for one for the citranges tested. The patterns of Na indicated that the concentrations of sour orange were always higher than both citranges.

N plays an important role in tree growth and development. We found that Carrizo citrange had the highest N concentrating. Our finding is in agreement with those of previous studies (Kaplankıran and Tuzcu, 1993; Taylor and Dimsey, 1993). The fact that sour orange had the lowest concentration was also supported by the results from these previous studies. Wutscher (1989) also found low N concentrations on the trees budded on sour orange. These can be explained by the low percentages of hairy root on sour orange when compared to the citranges which eventual result in lower utilization of N on the upper part of soil of the orchard which was in sandy-loam form.

When our results were compared to the previous studies similar patterns were observed among rootstocks for almost all elements tested. For example, K, Mg, Mn and Cu concentrations were highest on Carrizo citrange; P and Fe were highest on Troyer citrange and Ca, Na and Zn were highest on sour orange (Wutscher, 1989; Taylor and Dimsey, 1993; Georgiou, 2002; Tsakelidou et al., 2002; Perez-Zamora, 2004; Smith et al., 2004). The small differences on the absolute values of the mean can be explained by ecological differences and the scion cultivars.

We found that the mean Zn concentrations were under the optimum limits for both rootstocks and cultivars. Under survey of eastern Mediterranean citrus orchards, Tuzcu et al. (1981) found that Zn concentration levels were under the optimum range. Indeed, Zn deficiency is a common problem in many regions of world's citrus production. For example, 60% of American (Bell et al., 1997) and 28% of Pakistani (Ranjha et al., 2002) citrus orchards are Zn-deficient. We found that sour orange had the highest Zn concentrations supporting previous studies (Kaplankıran and Tuzcu, 1993; Georgiou, 2002; Tsakelidou et al., 2002). Zn deficiency in citrus orchards is believed to be caused by low soil Zn content and high pH.

The rootstocks certainly affect the yield and quality parameters in citrus production. Therefore, for an ideal production system most appropriate rootstocks/scion combination needs to be determined. Kaplankıran et al. (1999) indicated that the rootstocks with high N, K, Fe and Mn efficiency had positive effects on yield and quality. The fact that Carrizo citrange had the highest values for most of these elements indicates that Carrizo citrange is a good rootstock for Rhode Red Valencia and Valencia Late oranges. The results of Kaplankıran et al. (2008) supported this finding fact that the highest yield mean was recovered from this combination.

In conclusion, we demonstrated that the citrus rootstocks had different abilities to utilize plant nutrient elements. For N, K, Mg, Mn and Cu Carrizo citrange has the highest means while Troyer and sour orange the highest concentrations for P and Fe, and Ca, Zn and Na, respectively. Since the rootstocks had different abilities to utilize different elements, the optimum rootstock/scion combinations should be determined in addition to ecological conditions and the cultivar selections. When productivity, quality, scions/rootstock affinity, climatical and ecological conditions were considered, we recommended utilizations of Carrizo and Troyer citrange rootstocks for eastern Mediterranean region citrus production as they had higher ability to utilize many plant

Table 2. Means and mean separations of several plant nutrient elements for Valencia Late and Rhode Red Valencia oranges budded on Carrizo citrange, Troyer citrange and Sour orange.

Source	(%)						(mg / kg)			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
Cultivar	**2004**									
Rhode Red Valencia	2.30	0.15	1.15 a	5.37 a	0.34	0.10	87.3	71.0	25.7	11.1
Valencia Late	2.28	0.14	1.07 b	5.04 b	0.34	0.10	87.7	69.7	24.1	10.7
$LSD_{0.05}$	ns	ns	0.04	0.09	ns	ns	ns	ns	ns	ns
Rootstock										
Carrizo citrange	2.41 a	0.15 ab	1.23 a	4.90 b	0.37 a	0.08 b	87.8 ab	76.1 a	24.8 ab	12.8 a
Troyer citrange	2.27 b	0.16 a	1.10 b	5.01 a	0.35 b	0.09 b	90.8 a	60.6 b	23.7 b	11.1 b
Sour orange	2.20 c	0.14 b	1.01 c	5.69 a	0.30 c	0.12 a	84.0 b	74.4 a	26.2 a	8.9 c
$LSD_{0.05}$	0.06	0.01	0.05	0.12	0.01	0.01	4.2	6.8	2.0	1.3
Mean	2.29	0.15	1.11	5.20	0.34	0.10	87.5	70.4	24.9	10.9
Cultivar	**2005**									
Rhode Red Valencia	2.36	0.16	1.20 a	5.28 a	0.35	0.11	92.6	71.7	27.1 a	12.1
Valencia Late	2.36	0.16	1.15 b	4.95 b	0.35	0.10	93.3	76.1	21.5 b	11.7
$LSD_{0.05}$	ns	ns	0.05	0.10	ns	ns	ns	ns	1.8	ns
Rootstock										
Carrizo citrange	2.48 a	0.16 ab	1.28 a	4.85 b	0.38 a	0.09 b	93.6 a	79.6 a	23.7 b	13.4 a
Troyer citrange	2.34 b	0.17 a	1.15 b	4.90 b	0.36 b	0.10 b	97.7 a	64.8 b	23.3 b	12.0 b
Sour orange	2.27 c	0.15 b	1.09 c	5.59 a	0.31 c	0.13 a	87.6 b	77.3 a	25.9 a	10.3 c
$LSD_{0.05}$	0.06	0.01	0.06	0.13	0.01	0.01	5.1	6.2	2.2	1.4
Mean	2.36	0.16	1.18	5.12	0.35	0.11	93.0	73.9	24.3	11.9
Overall mean	2.33	0.15	1.14	5.16	0.34	0.10	90.25	72.13	24.60	11.42
Optimum range*	2.20-2.70	0.12-0.18	1.00-1.70	3.00-6.00	0.30-0.60	0.01-0.15	60-150	25-100	25-100	5.10-15.0

*Optimum ranges according to Marchal (1987)

nutrient elements playing important roles in productivity and quality.

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