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Tree Canopy Volume and Leaf Mineral Nutrient Concentrations of 'Redblush' Grapefruit on Twelve Rootstocks[1]

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Abstract

Tree growth, leaf fresh weight, dry matter and mineral nutrient concentrations and their relationships with yield in 'Redblush' grapefruit (*Citrus paradisi* Macf.) on twelve rootstocks under the desert conditions of southwest Arizona were studied over several years. Trees on Volkamer lemon (*C. limon* Burm. f.), Oklawaha sour orange (*C. aurantium* L.), rough lemon (*C. jambhiri* Lush) and Carrizo citrange [*C. sinensis* (L.) Osbeck x *Poncirus trifoliata* (L.) Raf.] had large canopy volumes and highe yields while those on Savage citrange [*C. sinensis* (L.) Osbeck x *P. trifoliata* (L.) Raf.], Ichang pummelo (*C. ichangensis* hyb.), Cleopatra mandarin (*C. reticulata* Blanco.), Swingle citrumelo (*C. paradisi* x *P. trifoliata*) and macrophylla (Alemow) (*C. macrophylla* Wester) were in low yield and small canopy group. 'Redblush' grapefruit trees on Palestine sweet lime (*C. limettiodes* Tan.) were in the high yielding group in spite of their small canopy volume. Trees on Savage citrange had the highest leaf percent dry matter, while those on Volkamer lemon had the lowest. Leaves of trees on macrophylla had the highest levels of N, Cu, Mn and Fe, but the lowest levels of Ca and Mg. Trees on all citranges and Swingle citrumelo had low leaf N, and those on citranges also had low leaf Zn and Mn. 'Redblush' grapefruit trees on Volkamer lemon and Ichang pummelo had the highest leaf Zn.

Introduction

The influence of rootstock on growth and yield has been documented for various citrus cultivars (2, 3, 4, 5, 6, 7, 15, 16, 17, 18, 19). Effects of rootstock on leaf mineral nutrient concentrations have been reported for mandarins (7, 10, 13) and oranges (10). Yield and leaf nutrient content of grapefruit on different groups of rootstocks in Texas were studied by Wutscher and Dube (15), Wutscher and Shull (16, 17, 18) and Wutscher et al. (19). 'Redblush' grapefruit trees on Swingle citrumelo had a significantly larger canopy and higher yield than those on Cleopatra mandarin or rough lemon (15). Grapefruit trees on Christiansen trifoliate orange (*P. trifoliata* (L.) Raf.) had the highest leaf N while those on Sun Chu Sha mandarin (*C. reticulata* Blanco.) had the lowest (15). In a different study, leaves of 'Redblush' grapefruit trees on macrophylla had high N and Mn, but those on Chinese box-orange (*Severinia buxifolia* (Poir) Ten.) had a high accumulation of K and Mn (17).

Although grapefruit is an important citrus crop in Arizona (1), there is no information on the influence of different rootstocks on growth and leaf nutrient levels. The objective of this study was to determine the effects of 12 rootstocks on growth, leaf fresh and dry weights and mineral nutrient concentrations and the relationships between these factors and yield in 'Redblush' grapefruit over several years. The effects of these rootstocks on the fruit quality was previously reported (3).

Materials and Methods

'Redblush' grapefruit was budded onto seedlings of twelve rootstocks in 1965. Trees were greenhouse grown in containers and planted in the field at the University of Arizona Yuma Mesa Agricultural Center in March 1966. The twelve rootstocks were: Volkamer lemon, Oklawaha sour orange, Palestine sweet lime, rough lemon, Carrizo

[1]This experiment was performed at the University of Arizona Yuma Mesa Agricultural Center, Yuma, Arizona.

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citrange, Taiwanica (*C. taiwanica* Than. & shim), macrophylla, Troyer citrange [*P. trifoliata* (L.) Raf. x *C. sinensis* (L.) Osbeck], Swingle citrumelo, Cleopatra mandarin, Ichang pummelo and Savage citrange. The budwood sources and budded trees were indexed and free of viruses at the time of planting. Tree spacing was 7.0 x 7.0 m, and the soil was a well drained Superstition sand (Typic Calciorthid, 80% sand) with a pH of 8.0 due to a high Na and Ca content.

Equal amounts of ammonium nitrate were applied in October, December, February and April every year, at an annual rate of 0.5 to 1.5 kg N/tree, depending on tree age. Nitrogen was applied at an annual rate of 1.5 kg/tree for the last 5 years (1984-1988). Trees were flood irrigated biweekly from April through September and monthly from October through March. Trees were not given any micronutrients after 1984 to evaluate rootstock mineral uptake efficiency. Pesticide was applied twice annually to control thrips and the orchard was disked as needed for weed control. Overall, tree spacing and other cultural practices in the experimental block were similar to those used in commercial groves.

The experiment design was randomized complete blocks with four replications and two trees per plot (total of 8 trees per rootstock). Fruit from each tree were harvested into 30 kg boxes and yield was recorded annually for 14 years. Tree canopy volume was calculated in March 1988 (22 years after planting) by Turrell's formula (14) using measurements of tree height and width: $V = 0.542 \times \text{height} \times \text{width}^2$

In mid-August of 1986, 1987 and 1988, thirty leaves per tree were sampled randomly from the middle of the last 6-month-grown, non-bearing shoots. Leaves were washed in a mild Liqui-nox detergent, rinsed with distilled water and dried in an air forced oven at 70°C to a constant weight and then reweighed. Leaves were analyzed for N by a Kjeldahl method (9). Potassium, Ca, Mg, Zn, Cu, Mn and Fe were determined after dry ashing (8) by atomic absorption spectroscopy (Video 11, Allied, Waltham, MA). Analyses of variance for cumulative yield over 14 years, tree canopy volume for 1988 and for 3-year means (1986, 1987 and 1988) for leaf fresh weight, dry matter content, percent dry matter and mineral nutrients are reported. Means were separated by Duncan's multiple range test when a significant F value existed.

Results and Discussion

Trees on the twelve rootstocks are ranked in Table 1 according to their cumulative yield. 'Redblush' grapefruit trees on Volkamer lemon, sour orange, Palestine sweet lime, rough lemon and Carrizo citrange were in the high yielding group, while trees on macrophylla, Troyer citrange, Swingle citrumelo, Cleopatra mandarin, Ichang pummelo and Savage citrange were in the low yielding group (Table 1). Trees on Swingle citrumelo had smaller canopy than those on rough lemon (Table 1) contrary to results in Texas (15). Cumulative yield was positively correlated to tree canopy volume in most rootstocks (Table 1). However, 'Redblush' grapefruit trees on Palestine sweet lime had high yield in spite of their small canopy volume. Trees on Savage citrange had the smallest tree canopy.

Leaves of 'Redblush' grapefruit trees on Swingle citrumelo and Taiwanica were heavier and had a higher dry matter content than those from trees on sour orange, palestine sweet lime, Ichang pummelo and Savage citrange (Table 1). Trees on Savage citrange had more dry matter in the leaves than those on other rootstocks (Table 1). The percent dry matter content of the leaves of these trees corresponds with a higher soluble solids in the fruit (3) which could be due to more efficient photosynthesis. Percent dry matter in the leaves of trees on other

Table 1. Effects of rootstock on 'Redblush' grapefruit yield, tree canopy volume and leaf fresh weight and dry matter[z]

Rootstock[y]	14-year cumulative yield (kg/tree)	Tree canopy volume 1988 (m^3)	Leaf fresh weight (g/leaf)	Leaf dry matter (g/leaf)	Leaf percent dry matter
VOL	2972 a[x]	148 bc	0.779 abcd	0.290 cd	37.2 f
SOU	2796 ab	181 ab	0.760 bcd	0.300 bcd	38.9 b
PAL	2687 abc	104 de	0.715 cd	0.273 d	38.3 bcde
RLE	2686 abc	166 ab	0.793 abc	0.295 bcd	37.3 ef
CAR	2660 abc	164 ab	0.828 ab	0.319 abc	38.5 bc
TAI	2630 bc	193 a	0.848 a	0.324 a	38.2 bcde
MAC	2620 bc	111 de	0.786 abcd	0.295 bcd	37.5 def
TRO	2366 cd	153 bc	0.827 ab	0.316 abc	38.2 bcde
SWI	2303 d	128 cd	0.857 a	0.329 a	38.4 bcd
CLE	2257 d	129 cd	0.788 abcd	0.304 abcd	38.7 b
ICH	2056 de	109 de	0.736 cd	0.278 d	37.7 cdef
SAV	1781 e	79e	0.708 d	0.283 d	40.1 a

[z]Each value of the leaf fresh weight, dry weight and percent dry matter is the mean of 1986, 1987 and 1988 (3 years) data with four two-tree replications per year.

[y]Abbreviations: VOL = Volkemer lemon; SOU = Oklawaha sour orange; PAL = Palestine sweet lime; RLE = Rough lemon; CAR = Carrizo citrange; TAI = *C. taiwanica;* MAC = *C. macrophylla;* TRO = Troyer citrange; SWI = Swingle citrumelo; CLE = Cleopatra mandarin; ICH = Ichang pummelo; SAV = Savage citrange.

[x]Mean separation within columns by Duncan's Multiple Range Test, P = 0.05.

rootstocks was also positively correlated to fruit soluble solids; thus, trees on Volkamer and rough lemon with the lowest soluble solids in the fruit (3) also had the lowest percent dry matter in the leaves (Table 1). Percent dry matter in the leaves of trees on different rootstocks did not correlate with the mineral nutrient concentrations. This suggests that the differences in nutrients in the leaves of trees on different rootstocks are a direct rootstock effect, not a dilution effect.

'Redblush' grapefruit trees on macrophylla, Palestine sweet lime and Volkamer lemon had higher leaf N than those on Carrizo citrange, Swingle citrumelo, Cleopatra mandarin, Ichang pummelo, sour orange, savage citrange, Taiwanica and Troyer citrange (Table 2). Trees on Volkamer lemon, Palestine sweet lime, rough lemon and macrophylla, were the only trees with sufficient leaf N according to conventional citrus leaf standard values (12). High leaf N in the trees on macrophylla is in agreement with a previous report from Texas (17). Since 'Redblush' tree canopy size on macrophylla were small (Table 1), those trees had a higher root/shoot ratio, leading to higher N levels (Table 2). Trees on carrizo and Troyer citranges had the lowest leaf N, which were in the deficient range (12), perhaps due to high-Ca and high pH soil conditions (11). A negative correlation coefficient was found between leaf N and leaf Ca ($r > -0.42$). This would suggest that annual nitrogen application should be greater than those used in our experiment (1.5 kg/tree). Trees on Savage citrange and Swingle citrumelo had intermediate leaf N (Table 2).

Trees on Swingle citrumelo had the highest leaf K (Table 2) because Swingle had a grapefruit parentage. This result is consistent with the previous report (17). The high leaf K in the trees on Swingle citrumelo is the reason for the high fruit acid content on these rootstocks (3). Trees on all citranges (Carrizo, Troyer and Savage) and Palestine sweet lime had lower leaf K than those on Swingle citrumelo and Ichang pummelo (Table 2). Trees on

Table 2. Effects of rootstock on leaf mineral nutrient concentrations of 'Redblush' grapefruit expressed on a dry weight basis.[z]

Rootstock[y]	N (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)
VOL	2.56 ab[x]	1.33 bcd	4.34 bc	.480 b	26.0 a	12.5 abc	14.5 b	48.5 bcd
SOU	2.28 def	1.29 bcd	5.70 abc	.402 e	20.4 abc	13.4 abc	11.5 cd	46.8 bcd
PAL	2.59 ab	1.19 cd	4.77 abc	.427 cde	24.0 ab	9.7 d	15.2 b	49.6 bc
RLE	2.50 bc	1.39 bc	5.38 abc	.437 bcde	23.8 ab	13.0 abc	12.8 c	45.7 bcd
CAR	2.19 fg	1.20 cd	6.00 ab	.556 a	15.2 c	13.9 ab	8.4 f	45.4 bcd
TAI	2.33 de	1.34 bcd	5.19 abc	.454 bcd	21.1 abc	13.3 abc	10.0 e	41.9 cd
MAC	2.67 a	1.40 abc	4.29 c	.359 f	20.7 abc	14.0 a	16.8 a	61.8 a
TRO	2.15 g	1.23 cd	5.01 abc	.548 a	18.0 bc	13.7 ab	8.2 f	45.8 bcd
SWI	2.23 efg	1.61 a	.414 de	20.1 abc	13.1 abc	10.8 de	42.3 cd	
CLE	2.27 efg	1.38 bc	5.58 abc	.466 bc	22.7 ab	10.9 cd	11.4 cde	40.3 d
ICH	2.39 cd	1.51 ab	5.14 abc	.415 de	26.6 a	11.3 bcd	12.2 cd	51.6 b
SAV	2.24 efg	1.12 d	5.91 ab	.421 cde	18.2 bc	13.3 abc	9.9 e	43.7 bcd

[z]Each value is the mean of 1986, 87 and 88 (3 years), four replications with two trees per year.
[y]Abbreviations: VOL = Volkemer lemon; SOU = Oklawaha sour orange; PAL = Palestine sweet lime; RLE = Rough lemon; CAR = Carrizo citrange; TAI = *C. taiwanica;* MAC = *C. macrophylla;* TRO = Troyer citrange; SWI = Swingle citrumelo; CLE = Cleopatra mandarin; ICH = Ichang pummelo; SAV = Savage citrange.
[x]Mean separation within columns by Duncan's Multiple Range Test, P = 0.05.

all rootstocks except those on Savage and palestine sweet lime had sufficient leaf K according to the citrus leaf standard values (12). Our experimental trees had never received any K fertilizer, but irrigation water which was supplied from the Colorado River and the soil apparently had sufficient levels of K for grapefruit.

Trees on Carrizo citrange and Swingle citrumelo had significantly higher leaf Ca than those on macrophylla (Table 2). Leaf Mg was highest in the trees on Carrizo and Troyer citrange, but lowest in the trees on macrophylla (Table 2). 'Redblush' grapefruit leaf Mg and K were negatively correlated in most rootstocks (r = -0.50).

Leaf Zn in the trees on Volkamer lemon and Ichang pummelo was higher than that in trees on all citranges (Table 2).

Trees on macrophylla had relatively high levels of leaf Mn and Fe compared to those on all other rootstocks (Table 2). Leaf N was always correlated negatively with MG (r = 0.61) and positively with Mn (r = 0.51) and Fe (r = -0.50) during all 3 years of testing.

Conclusion

In rootstock selection, physiological and horticultural effects on the scion cultivar of each rootstock, including tree growth, mineral uptake efficiency, yield and fruit quality should be considered. Volkamer lemon is recommended for 'Redblush' grapefruit in the desert Southwest. Trees on this rootstock had the highest production (3) and leaves had high levels of Zn (Table 2). Zinc deficiency is a major problem on the high-pH soils of the Southwest.

Carrizo citrange is a desirable rootstock for 'Redblush' grapefruit. Trees on this rootstock had large fruit (3) and high production (Table 1). However trees on Carrizo citrange had low leaf N and a higher rate of nitrogen than 1.5 kg/tree (the rate used in this experiment) should be applied when Carrizo citrange is used.

'Redblush' grapefruit trees on macrophylla had higher leaf N, Cu, Mn and Fe than those on all other rootstocks. Trees on macrophylla were precocious and had the highest yield efficiency (3) due to their small canopy

(Table 1). All of these factors suggest that macrophylla could be a desirable rootstock, particularly for a closer spacing than 7.0 x 7.0 m. However, yield on this rootstock gradually declines with tree age (3) and a long term planting of 'Redblush' grapefruit on macrophylla is not advisable.

Contrary to the results in Texas (15, 17), 'Redblush' grapefruit on Swingle citrumelo did not perform satisfactorily. Trees on this rootstock had low production (Table 2), and low leaf N in spite of their high leaf K content (Table 2). Cleopatra mandarin and Ichang pummelo are not recommended for grapefruit under the desert climatic conditions of the Southwest. Savage rootstock can only be used if high fruit soluble solids (3) and trees with small canopies are the objectives in production; otherwise, trees on this rootstock had poor yield.

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