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Evaluation of rootstocks for the Cyprus local lemon variety 'Lapithkiotiki'

A. Georgiou *

Agricultural Research Institute, P.O. Box 22016, Nicosia, Cyprus

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ABSTRACT

The effect of various rootstocks on yield, yield efficiency, tree size and fruit quality of the local lemon variety 'Lapithkiotiki' (*Citrus limon* (L.) Burm. F.) was studied under Cyprus conditions. Total cumulative yield over 13 years of production was the highest on rough lemon (*C. jambhiri* Lush) followed by that on Volkameriana (*C. volkameriana* Ten. & Pasq.), Yuma Ponderosa lemon (*C. limon* (L.) Burm. F.), sour orange (*C. aurantium* L.), *Citrus macrophylla* Wester, Morton citrange (*C. sinensis* cv. Washington navel × *Poncirus trifoliata* (L.) Raf.), Yuma citrange, Rangpur lime (*C. limonia* Obs.), Palestine sweet lime (*C. limettioides* Tan.), C-32 citrange and Citremon 1449 (*C. limon* × *P. trifoliata*), although no statistically significant differences were found between sour orange, the commercial rootstock used in Cyprus, and the other above mentioned rootstocks. Next in order as regards to total cumulative yield was Cleopatra mandarin (*C. reticulata* Blanko.) followed by Carrizo citrange, with statistically significant differences compared with sour orange. Trees on Citrumelo CPB-4475 (*C. paradisi* Macf. × *P. trifoliata*) and C-35 citrange died 3–4 years after grafting. Canopy volume was the lowest for trees on Cleopatra mandarin and Carrizo citrange. Yield efficiency *A*, expressed as total cumulative yield per trunk cross-sectional area, was the highest on *C. macrophylla* and lowest on Carrizo citrange. Rootstock significantly affected fruit size and weight, rind thickness, juice content, brix, total acids and brix:acid ratio. The results of the present study reveal that the most promising rootstocks that may replace sour orange for the local lemon variety 'Lapithkiotiki' under Cyprus conditions are Volkameriana, Yuma Ponderosa lemon, *C. macrophylla* and Citremon 1449.

Citrus is a major and valuable crop in Cyprus and it is by far one of the most important export crops of the island. About 5500 ha are presently cultivated with citrus representing 4% of the total cropped area and 15% of the total irrigated area. Citrus production reaches 127,000 tonnes of which 34% are oranges, 22% grapefruit, 16% lemons and 28% mandarins and mandarin hybrids.

The most important lemon variety grown commercially in Cyprus is the local variety 'Lapithkiotiki' and, as for all other citrus cultivars, the main rootstock used is sour orange. This study was conducted in order to evaluate the effect of various rootstocks on yield, yield efficiency, tree size and fruit quality of the local lemon variety 'Lapithkiotiki' under Cyprus conditions and to identify rootstocks of superior or similar characteristics that may replace sour orange.

1. Materials and methods

Citrumelo CPB-4475, C-35 citrange and 11 other rootstocks that appear in Table 1 were tested in the present study. Seeds of rootstocks were obtained from the Citrus Research Center, University of California, Riverside, except those of sour orange and Palestine sweet lime, which were obtained locally from selected healthy trees. One-year-old seedlings were field planted at the Citrus Experimental Station, Akhelia (Latitude, 35°N; Longitude, 32°E) in 1991 and were T-budded in 1993. The budwood used came from a single tree, raised from budwood cleaned by the Citrus Research Center, University of California, Riverside. The experimental design was randomised complete block, with six replications and plot size consisted of one tree. Tree spacing was 6.7 m × 6.7 m.

The soil is a vertisol clay underlain at about 0.9 m by a carbonate layer (60% $CaCO_3$). The surface soil layer contains 1.5% organic matter and 20% $CaCO_3$ and has a pH value of 8.0 and an ECe value of 1.5 dS m^{-1} throughout the profile.

Trees were irrigated by minisprinklers from April to November with a frequency of 5–8 days. Irrigation requirements were based on class A pan evaporation. Dam water was used for irrigation with a pH of 7.6 and an electrical conductivity of 0.7 dS m^{-1}, containing (in mequiv. L^{-1}): Ca-3.3, Mg-2.3, Na-2.2, K-0.1, SO_4-2.2, CO_3-0.2, Cl-1.4 and HCO_3-4.2. N, P and K were applied in early spring, the amounts increasing progressively each year to reach 214 kg N ha^{-1} as ammonium sulphate and ammonium nitrate, 82 kg P ha^{-1} as triple superphosphate and 170 kg K ha^{-1} as potassium sulphate. The grove was cultivated, pruned and sprayed according to local practices.

* Tel.: +357 22403113; fax: +357 22316770.
E-mail address: georgiou@arinet.ari.gov.cy.

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Table 1
Effect of rootstock on tree size, total cumulative yield, yield efficiency and scion:stock ratio of the lemon variety 'Lapithkiotiki' 13 years after budding.

Rootstock	Canopy height (m)	Canopy width (m)	Canopy volume (m^3)	Trunk cross-sectional area (cm^2)	Cumulative yield (kg/tree)	Yield efficiency		Scion: stock ratio b
						A ($kg\,cm^{-2}$)	*B* ($kg\,m^{-3}$)	
Sour orange	5.14 ab[xy]	5.90 A	93.26 A	528.05	1899.6 abc	3.71 cd	20.56	1.09 a
Yuma Ponderosa lemon	5.31 ab	5.50 ABC	87.01 A	413.98	1941.7 abc	4.63 abc	23.15	0.92 abcd
Volkameriana	4.78 bcd	5.67 AB	81.01 AB	579.43	1970.3 ab	3.91 cd	24.56	1.07 ab
Rough lemon	4.9 abcd	5.31 ABC	73.09 AB	379.68	2064.6 a	5.57 ab	29.25	0.93 abcd
C. macrophylla	5.02 abc	5.05 BC	66.97 AB	327.72	1897.5 abc	5.86 a	27.96	0.98 abc
Palestine sweet lime	4.93 abcd	5.00 BC	66.82AB	368.77	1684.6 abc	4.65 abc	27.43	0.88 abc
Rangpur lime	4.93 abcd	5.05 BC	70.76 AB	420.04	1755.5 abc	4.28 bc	30.73	1.00 abc
Cleopatra mandarin	4.12 d	4.75 C	51.38 B	335.01	967.7 d	3.19 cd	20.59	0.99 abc
Yuma citrange	5.72 a	5.13 ABC	79.89 AB	388.00	1792.4 abc	4.57 abc	22.34	0.74 d
Morton citrange	5.11 ab	5.29 ABC	77.03 AB	472.72	1809.5 abc	4.49 abc	24.92	0.84 cd
Carrizo citrange	4.25 cd	4.78 C	51.24 B	384.93	875.5 d	2.44 d	17.17	0.95 abc
C-32 citrange	4.77 bcd	5.27 ABC	71.66 AB	483.80	1548.1 bc	3.36 cd	23.43	0.86 cd
Citremon 1449	4.81bcd	5.10 BC	66.76 AB	421.24	1484.7 c	3.52 cd	23.03	1.00 abc
SD	0.58	0.55	19.91	140.61	319.5	1.06	7.09	0.13

x = Means followed by different letters are significantly different at 1% (low case), 5% (capitals).
y = Mean separation by Duncan's multiple range test.

Yield per tree was recorded annually (1995–2007). Each year, fruits were harvested during the October–December period. From 1995 to 2007, 10 fruits per tree were randomly collected and analysed for juice content, brix and acid concentration, fruit diameter and rind thickness. Brix was measured with a hydrometer at 20 °C; total acids (TA) were determined (as citric acid equivalent) by titrating with NaOH (Anon., 1946). Fruit weight was determined from 150 to 300 fruits.

Canopy height and -diameter and trunk circumference were measured annually, after harvest. Canopy volume was calculated using the equation for one half of a prolate spheroid: $V = 0.5236HD^2$ (H = canopy height, D = canopy diameter) (Castle and Phillips, 1980). Trunk circumference was measured 15 cm above the bud union and was converted into trunk cross-sectional area (TCSA). Yield efficiency was estimated as the ratio of total cumulative yield for the period 1995–2007 to TCSA estimated in 2007 (yield efficiency *A*) or as total cumulative yield to canopy volume estimated in 2007 (yield efficiency *B*). Scion and stock circumference were measured in December 2007 just above and below the bud union and their ratio was determined.

Data were analysed using SAS procedures. Analysis of variance was used to examine rootstock effects on yield and fruit quality characteristics. Means were compared by Duncan's New Multiple Range Test.

2. Results and discussion

2.1. Tree health

All trees on Citrumelo CPB-4475 and C-35 citrange rootstocks died 3–4 years after grafting due to incompatibility responses, expressed as bud-union crease. Incompatibility problems of other lemon scions with citrumelo and C-35 citrange have been previously reported (Kirkpatrick et al., 1962; Sarooshi and Broadbent, 1992; Roose, 1995; Miller et al., 1996; Gardiazabal et al., 2001).

Two trees on Palestine sweet lime, two on rough lemon and two on Rangpur lime died probably because of phytophthora. In addition, two trees, one on C-32 citrange and one on Morton citrange declined from unknown causes.

2.2. Tree size

Rootstock significantly affected canopy height, -width and -volume, but not TCSA (Table 1). It is important that no rootstock compared with sour orange significantly increased either canopy height, -width, or -volume. However, compared with sour orange, *Citrus macrophylla*, Palestine sweet lime, Rangpur lime and Citremon 1449 significantly decrease canopy width, whereas canopy height, -width and -volume were significantly decrease by Cleopatra mandarina and Carrizo citrange.

2.3. Yield

Total cumulative yield, over 13 years of production, was the highest on rough lemon followed by that on Volkameriana, Yuma Ponderosa lemon, sour orange, *C. macrophylla*, Morton citrange, Yuma citrange, Rangpur lime, Palestine sweet lime, C-32 citrange and Citremon 1449, although no statistically significant differences were found between sour orange and the other above mentioned rootstocks. Total cumulative yield on Cleopatra mandarin was next in order, followed by that on Carrizo citrange. The last two rootstocks showed statistically significant differences in cumulative yield compared with sour orange.

Yield efficiency *A* (kg/TCSA) was the highest on *C. macrophylla* followed by that on rough lemon and lowest on Carrizo citrange. Yield efficiency *A* on all rootstocks except on *C. macrophylla* and rough lemon was similar to that on sour orange. However, yield efficiency *B* (kg/tree volume) on all rootstocks was as high as on sour orange. In general, the results obtained regarding yield and yield efficiency are in agreement with those reported for other lemon varieties (Simon et al., 1986; Tuzcu et al., 1992; Roose, 1996; Gardiazabal et al., 2001).

2.4. Scion:stock ratio

Trees on most rootstocks had smooth bud unions. However, as indicated by the ratio of the circumference of the scion to that of the rootstock, Yuma citrange tended to grow more rapidly than the scion. Yuma citrange behaved similarly to Nova, Clementine mandarins and Shamouti orange (Georgiou and Gregoriou, 1999; Georgiou, 2000, 2002).

2.5. Fruit quality

Rootstock significantly affected all fruit quality indicators studied except for the shape of fruits (Table 2). Excepting Cleopatra mandarin which significantly decreased horizontal fruit diameter, no other rootstock reduced fruit size or weight compared with sour orange. On the contrary, Yuma Ponderosa lemon, Volkameriana, rough lemon, *C. macrophylla*, Palestine sweet lime, Rangpur lime, Carrizo citrange and Citremon 1449 significantly increased both