Potential Rootstocks For 'Redblush' Grapefruit In The Desert

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ABSTRACT

Effects of 12 rootstocks on yield, yield efficiency, bearing potential and quality of 'Redblush' grapefruit were measured and potential rootstocks recommended for the arid climate of southwest Arizona. Trees on 'Palestine' sweet lime and 'Volkamer' lemon produced high cumulative yield but small fruit. Trees on Macrophylla (Alemow) produced higher yields after 5 years of planting, and had significantly higher mean yield efficiency than trees on other rootstocks. Thus, Macrophylla rootstock could be a good choice for 'Redblush' at the standard spacing and perhaps at high density spacing in southwest Arizona. Fruit of trees on 'Carrizo' and 'Troyer' citranges were largest. Trees on 'Savage' citrange had lowest yield, thinnest peel and highest levels of total soluble solids and soluble solids/acid ratio. Fruit of trees on 'Swingle' citrumelo or C.P.B. 4475 rootstock consistently had higher percentage acid than those on other rootstocks. Considering yield and/or various quality factors, 'Volkamer' lemon, rough lemon , 'Palestine' sweet lime, 'Oklawaha' sour orange and particularly 'Carrizo' citrange are suitable for 'Redblush' grapefruit in the arid Southwest. 'Savage' citrange, 'Ichang' pummelo , 'Cleopatra' mandarin , and 'Swingle' were poor yielding rootstocks for 'Redblush ' grapefruit, and therefore undesirable for planting under the standard spacing of this experiment. 'Savage' and 'Swingle' might be good choices at higher densities because they have yield efficiency, high maximum bearing potential and quality.

INTRODUCTION

Yield, fruit quality, resistance to diseases, and soil adaptability are some of the important criteria for selecting rootstocks. Selection for yield alone is an unsatisfactory strategy to follow in evaluating scion/rootstock for fresh market fruit, as yield and quality are often inversely related. Our objective was to evaluate long-term effects of 12 rootstocks on yield and quality of 'Redblush' grapefruit grown in Arizona. This long-term evaluation enables us to identify potential rootstocks for the arid regions of the southwest.

MATERIALS AND METHODS

'Redblush' grapefruit was budded on 12 rootstocks. Trees were grown in the University of Arizona, Yuma Mesa Agricultural Center in 1966. The 12 rootstocks were: 'Volkamer' lemon, Macrophylla, rough lemon, 'Swingle' citrumelo or C.P.B. 4475, 'Carrizo' citrange, 'Troyer' citrange, 'Taiwanica', 'Palestine' sweet lime, 'Oklawaha' sour orange, 'Cleopatra' mandarin, 'Ichang' pummelo, and 'Savage' citrange. Tree spacing was 7 x 7 m; the soil was Superstition sand, with the top 20 cm mixed with silt (Typic Calciorthid, sandy, mixed, hyperthermic; 80% sand) with a pH of 8.0. Overall, tree spacing and cultural practices in the experimental block were similar to those in commercial groves.

The experimental design consisted of randomized complete blocks with 4 blocks (replications) per rootstock and 2 trees per block (replication). Fruit from each tree was harvested in 30 kg boxes, and the yield was recorded for 14 years between 1971 and 1986. The number of fruit per tree was estimated by dividing total yield per tree into the average fruit weight in 8 years. Trunk cross-sectional area was measured annually. Yield efficiency was calculated as yield (kg per tree)/cm^2 trunk cross-sectional area for 14 years.

Maximum number of trees per hectare was predicted by the following procedures:
1) The number of trees under the standard (commercial) spacing of this experiment was 202 per hectare (82 trees per acre). Bearing potential per hectare was calculated in 1986 (after 20 years of planting), by the formula: cross-sectional area in 1986 x current standard number of trees per hectare.
2) Rough lemon rootstock was considered as the standard rootstock since it is the most widely used rootstock in the southwest Arizona. The bearing potential of 'Redblush' trees on each rootstock was subtracted from that of the standard rootstock to calculate deviation bearing potential of trees on each rootstock from the standard.
3) The deviation in step 2 was divided into the cross-sectional area of each rootstock in 1986 to calculate the number of trees per hectare that could be added to or subtracted from the current standard spacing.
4) The number in step 3 was added to or subtracted from the the current standard number of trees per hectare to compute the maximum potential number of trees per hectare for each rootstock.

Fruit weight, juice volume per fruit, percentage juice (per fruit weight), specific gravity, peel thickness, total soluble solids, percentage titratable acid, and total soluble solid/acid ratio were measured in early February for 8 years between 1976 and 1986. Ten fruit per tree were sampled randomly for quality evaluation in each testing year. Fruit were weighed and cut in half. Peel thickness, juice volume, specific, total soluble solids, and total acids (as percentage citic acid per juice), and total soluble solids to acids ratio were measured.

RESULTS AND DISCUSSION

Yield

Trees on Macrophylla were more precocious than those on all other rootstocks. Trees on Macrophylla also had significantly higher yield efficiency (yield/trunk cross section) than trees on all other rootstocks over the 14-year period (Table 1). Trees on 'Cleopatra' mandarin and 'Taiwanica' had low production until 9 years after planting. Trees on 'Volkamer' lemon, rough lemon, 'Carrizo' citrange, 'Oklawaha' sour orange and 'Palestine' sweet lime were in the high cumulative yielding group, while trees on 'Savage' citrange, 'Ichang' pummelo, 'Cleopatra' mandarin, and 'Swingle' citrumelo were in the low-yielding category (Table 1).

Trees on'Swingle' and 'Savage' had small canopies. These trees, however, had relatively higher yield efficiency than trees on most other rootstocks, calculated either by formula yield/trunk cross section (Table 1) or by yield/canopy volume (data not shown). Our prediction showed that a larger number of trees per hectare can be planted if Macrophylla, 'Savage' citrange and 'Swingle' rootstocks are used. Maximum potential yield was predicted to be high for trees on Macrophylla, 'Swingle', and 'Palestine' lime, and low for trees on 'Cleopatra' mandarin rootstocks (Table 1). These predictions were made based on the assumption that tree volume is proportional with the cross-sectional area.

Fruit size

Fruits of trees on 'Carrizo' and 'Troyer' citranges were larger than fruit from the other rootstocks, (Table 2). Trees on 'Carrizo' citrange produced the largest mean fruit size over 8 years (Table 2). Their total cumulative yield over 14 years was statistically equal to that of trees on 'Volkamer' lemon, which numerically had the highest total yields (Table 1). This leads us to suggest that trees on 'Carrizo' produce optimal yields (size and number) when total yield alone is the parameter of interest. Minor differences were observed in length/diameter ratio (L/D) or "sheep nose" shape measurement of fruit from different rootstocks. None of the rootstocks produced trees having fruit with a length-to-diameter ratio of more than 0.95, indicating that "sheep nose" was not a significant quality deterrent.

Peel thickness

Fruit in our experiment had generally thicker peel than those in Texas (1, 2, 3), perhaps because of higher temperatures in Yuma. Fruit from trees on 'Taiwanica', Macrophylla, sour orange, and 'Ichang' had significantly thicker peel than those from 'Savage' citrange (Table 2). Fruit from trees on 'Swingle', 'Troyer', and 'Cleopatra' had the same thickness (Table 2); this data agrees with Wutscher and Dube (3).

Juice volume per fruit and percent juice by weight

Fruit from trees on 'Carrizo' citrange had significantly higher volume of juice per fruit than trees on sour orange and 'Taiwanica' (Table 2). Percentage juice in fruit from trees on 'Palestine' sweet lime and Macrophylla was significantly higher than the percentage of juice in fruit from trees on 'Swingle' citrumelo, 'Taiwanica', sour orange, 'Cleopatra' mandarin, and 'Ichang' pummelo (Table 2).

Total soluble solids

Rootstocks strongly influenced total soluble solids of scion fruit (Table 2). 'Redblush' on 'Savage' citrange and sour orange rootstocks had the highest soluble solids; fruit from trees on 'Volkamer' lemon, rough lemon, and Macrophylla were among the lowest (Table 2). Differences in soluble solids between trees on 'Volkamer' lemon and 'Savage' citrange may be due to their yield differences. Trees on 'Savage' had the lowest, and those on 'Volkamer' lemon had the highest number of fruit per tree (Table 1). More of the carbohydrate resources of trees on 'Savage' may have been partitioned into the smaller number of fruit, resulting in the observed high levels of total soluble solids. Fruit from trees on sour orange had high soluble solids (Table 2) in spite of their high yield (Table 1). Fruit from trees on 'Savage' citrange, sour orange and 'Swingle' citrumelo had significantly higher soluble solids than those on Macrophylla rootstock (Table 2). Specific gravity of fruit from trees on all rootstocks were generally proportional to their soluble solids (data not shown).

Total acids

Fruit from trees on 'Swingle' citrumelo had significantly higher total acids, while fruit from trees on Macrophylla rootstock had the lowest acids (Table 2). 'Redblush' fruit on 'Volkamer' lemon, rough lemon, and 'Palestine' sweet lime rootstocks were also among the low acid fruit (Table 2).

Soluble solids/acid ratio

Fruit in this experiment generally had a higher soluble solids/acid ratio than those from Texas (1, 2, 3). 'Redblush' fruit on 'Swingle' citrumelo, rough lemon, 'Taiwanica', and 'Volkamer' lemon had the lowest ratio. 'Redblush' fruit on 'Savage' citrange, Macrophylla, 'Carrizo' citrange, 'Troyer' citrange, sour orange, and 'Cleopatra' mandarin had the highest mean soluble solids/acid ratio (Table 2). High total soluble solids in fruit from trees on 'Savage' citrange is mainly responsible for the high soluble solids/acid ratio in this rootstock, whereas the high acid content of fruit from trees on 'Swingle' citrumelo results in a low soluble solids/acid ratio (Table 2).

CONCLUSIONS

In our long-term study, trees on 'Volkamer' lemon and 'Palestine' sweet lime had high yield, but poor fruit quality, when grown on sandy soil and in arid climatic conditions of southwest Arizona. Although trees on 'Volkamer' lemon produced high yield, large canopy volume and/or large trunk cross-sectional area of trees on this vigorous rootstock resulted in their having the same or lower yield efficiency than trees on slower growing rootstocks

(Table 1). However, 'Volkamer' lemon and 'Palestine' sweet lime are desirable rootstocks for 'Redblush' at standard spacing when yield is the primary goal of the growers. Trees on Macrophylla rootstock were precocious, had relatively high cumulative yield, significantly higher yield efficiency, and predicted potential yield per acre than trees on other rootstocks (Table 1). 'Redblush' fruit on this rootstock had a high soluble solids/acid ratio that allowed fruit to reach the minimum solid/acid standard for harvesting earlier than those on other rootstocks. Because of these desirable characteristics, Macrophylla could be a good choice for planting at standard spacing or higher densities in southwest Arizona.

Trees on sour orange had high yield and fruit quality (Tables 1 and 2). Sour orange is resistant to foot rot; considering yield and quality parameters, it may be a good rootstock for 'Redblush' on the sandy soil areas of southwest Arizona. Trees on rough lemon were vigorous and fruit quality was poor. However, rough lemon is suitable for planting in Arizona because 'Redblush' trees on this rootstock produce high yields and are drought-tolerant due to their extensive root system on sandy soil (Table 1). Trees on 'Carrizo' rootstock had high yields, with larger and juicier fruit than those on other rootstocks. This rootstock can also be recommended for planting on the sandy soil of southwest Arizona.

'Redblush' trees on 'Savage' citrange, 'Ichang' pummelo, 'Cleopatra' mandarin, and 'Swingle' citrumelo had relatively lower yield than those on other rootstocks (Table 1). Therefore, these rootstocks are not suitable for 'Redblush' at the spacing used in this experiment. However, 'Savage' citrange and 'Swingle' citrumelo might be good choices for planting at higher densities, because they increased yield efficiency and quality. Also, it was predicted that 'Redblush' trees on these rootstocks would have high production on a per hectare basis.

REFERENCES

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Table 1. Influence of rootstock on yield and bearing potential in 'Redblush' grapefruit

Rootstocks[z]	Cum.yield 14 Years (kg/Tree)	Yield efficiency mean 14 Yrs. (kg/cm^2)	Number of fruit per tree Avg.of 8 Yrs.	Bearing potential in 1986(cm^2)	Diviation of bearing potential from Std.(cm^2)	Trees to be added (A) or dropped(D) per hectar	Predicted potential number trees per Hectar	Predicted maximum potential cum.yield per Hectar (MT)
Vol	2972a[y]	0.69cde	591a	108,272ab	+ 9,696	18D	184	547
Mac	2620bc	0.95a	527ab	65,246d	-33,333	103A	305	799
Rle	2686abc	0.70cde	511ab	98,576b	-0-	-0-	202	543
Cit	2303d	0.82b	530d	74,134d	-24,442	67A	269	620
Car	2660abc	0.64efg	502abc	106,656ab	+ 8,080	15D	187	497
Tro	2366cd	0.66efd	429d	95,142bc	- 3,434	7A	209	494
Tai	2630bc	0.56g	492c	122,412a	+23,836	39D	163	429
Pal	2687abc	0.74bcd	511ab	81,406cd	-17,170	43A	245	658
Oso	2796ab	0.58fg	545ab	123,422a	+24,846	41D	161	450
Cle	2257d	0.59fg	413d	111,302ab	+12,726	23D	179	404
Ich	2056de	0.73bcde	359e	80,194cd	-18,382	46A	248	510
Sav	1781e	0.77bc	371e	71,912d	-26,664	75A	277	493

z Abbreviations: Vol: 'Volkamer' lemon; Mac - C. macrophylla; Rle: Rough lemon; Cit - 'Swingle' citrumelo; Car - 'Carrizo' citrange; Tro - 'Troyer' citrange; Tai - C. taiwanica; Pal - 'Palestine' sweet lime; Oso - 'Oklawaha' sour orange; cle - 'Cleopatra' mandarin; Ich - 'Ichang' pummelo; Sav - 'Savage' citrange

y Mesa separation within the columns by Duncan's Multiple Range Test, 5% level.

Table 2. Influence of rootstock on fruit quality of 'Redblush' grapefruit.

	Fruit weight (g)	Peel thickness (mm)	Juice volume (ml/fruit)	Percent juice (% of Fruit Wt.)	Total soluble solids (°Brix)	Total acid (% in Juice)	Total Soluble solids/total acid Ratio
Vol[y]	357b[x]	7.8abc	161ab	46.5abc	8.8e	1.36e	6.6c
Mac	363ab	7.9ab	165ab	47.1ab	8.9e	1.28f	7.0a
Rle	367ab	7.8abc	166ab	46.6abc	8.9e	1.36e	6.6c
Cit	374ab	7.5bc	164ab	45.6cd	10.2bc	1.61a	6.4d
Car	381a	7.6bc	171a	46.5abc	9.9c	1.43cd	7.0a
Tro	380a	7.5bc	168ab	45.9bcd	9.9c	1.45c	6.9ab
Tai	368ab	8.1a	160b	45.0d	9.4d	1.42cd	6.6c
Pal	354b	7.6bc	162ab	47.3a	9.3d	1.39de	6.7bc
Oso	366ab	7.9ab	160b	45.4cd	10.4ab	1.52b	6.9ab
Cle	373ab	7.8abc	165ab	45.7cd	9.9c	1.44c	6.9ab
Ich	373ab	7.9ab	161ab	44.8d	10.0c	1.50b	6.7bc
Sav	366ab	7.4c	164ab	46.4abc	10.6a	1.52b	7.1a

[z] Each value in the table is the mean of 8 years of data with 4 replications per year and 2 trees per replication.

[y] Abbreviations: Vol - ' Volkamer' lemon; Mac - C. macrophylla; Rle - Rough lemon; Cit - 'Swingle' citrumelo; Car - 'Carrizo' citrange; Tro - 'Troyer' citrange; Tai - C. Taiwanica; Pal - 'Palestine' sweet lime; Oso - 'Oklawaha' sour orange; Cle - 'Cleopatra' mandarin; Ich - 'Ichang' pummelo; Sav - 'Savage' citrange.

[x] Mean separation within columns by Duncan's Multiple Range Test, 5% level.