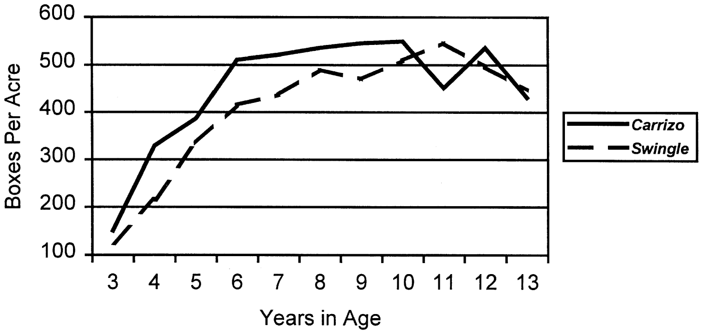

Figure 1. Estimated boxes per acre for 'Hamlin' by tree age and sorted by Swingle and Carrizo rootstocks.

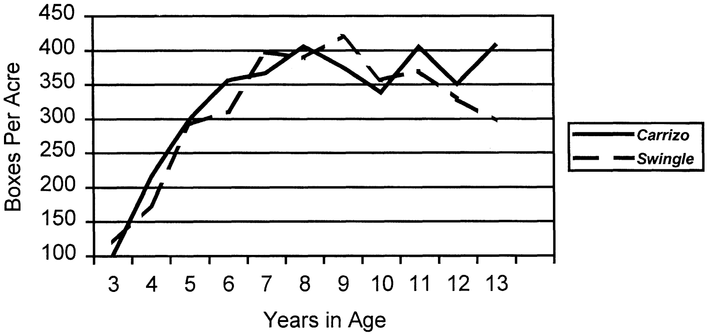

Figure 2. Estimated boxes per acre for 'Valencia' by tree age and sorted by Swingle and Carrizo rootstocks.

erage yields for 'Hamlin', 'Valencia', and 'Rohde Red Valencia' scion varieties through 13 years of tree age. 'Hamlin' blocks generally outperform 'Valencia' blocks in terms of boxes and pounds solids per acre. The reverse is true in terms of pounds solids per box, where 'Valencia' scion varieties produce more than 'Hamlin' scion varieties. While these results may confirm what growers already knew, this study provides growers with a benchmark from which to evaluate the performance of their own groves. Given the above average level of management among the growers who are participating in this study, the average yields reported from this study are likely to be higher than a region-wide average. However, long-term success will require a grower to set production goals at a level higher than a region-wide average. Therefore, the benchmark provided by this study should help growers achieve long-term success.

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EVALUATION OF ORANGE TREES BUDDED ON SEVERAL ROOTSTOCKS AND PLANTED AT HIGH DENSITY ON FLATWOODS SOIL

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Abstract. **The performance of 'Valencia' orange trees on Swingle citrumelo (Swi), Cleopatra mandarin (Cleo), Milam lemon (Mil), and Volkamer lemon (Volk) rootstocks was evaluated on the flatwoods soil of southwest Florida. Leaf mineral concentration, growth, fruit production and quality were measured four and seven years after planting in a closely-spaced setting (19 ft by 9 ft) in a commercial grove. Compared to Florida citrus leaf standards, leaf mineral concentration values were within the optimum to the high range. Yield efficiency expressed as lb solids/yard^3 of canopy and juice quality in terms of juice content, Brix, and lb solids/box increased with tree age. Tree and fruit size were the highest for Volk and the lowest for Cleo. Fruit yield was the highest for Volk. However, yield expressed in lb solids/acre was not significantly different between Volk and Swi due to the higher solids/box for Swi. Yield efficiency was also higher for Swi than for Volk. Juice content and soluble solids in the fruit were higher for Swi and Cleo than for both lemon rootstocks. Financial analysis showed that at high density planting, trees on Swi were the most profitable.**

Citrus is of major economic importance in many counties of Florida, with a total economic impact exceeding $8 billion a year. In Florida, citrus groves occupy approximately 845,000 acres with over 107 million trees (Florida Agricultural Statistics Service, 1999). Rootstocks have had a substantial role in the development of the Florida citrus industry. Prior to about 1970, the industry was

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well served by two rootstocks, rough lemon (*Citrus jambhiri* Lush) and sour orange (*C. aurantium* L.), for most cultivars. Since the 1970s and 1980s, rootstocks have become a more critical issue than in previous years largely because of blight and the increased incidence of tristeza and frequency of freezes (Castle et al., 1993). Because of the devastating freezes that occurred in December 1983, January 1985, and December 1989, new planting increased tremendously, especially in southwest and southeast Florida (Jackson and Davies, 1999). Furthermore, tree spacing has become an increasingly important consideration in citrus rootstock management because of the benefits of higher tree densities on early production and financial returns (Wheaton et al., 1995).

The effect of rootstocks on citrus tree growth, yield, and fruit quality has been intensively studied in many citrus producing areas of the world including Florida (Castle and Phillips, 1980; Continella et al., 1988; Economides and Gregorion, 1993; Fallahi and Rodney, 1992; Fallahi et al., 1989; Gardner and Horanic, 1961, 1966; Grisoni et al., 1989; Monteverde etal., 1988; Roose et al., 1989; Rouse and Maxwell, 1979; Wheaton et al., 1991; Zekri, 1996, 1997). Most studies were conducted on well-drained deep sandy soils on the ridge in the central part of the Florida peninsula. Studies on the shallow, poorly drained soils of southwest Florida are lacking. Since the environmental conditions and cultural practices are unique in southwest Florida and vary considerably from those in different parts of the commercial citrus belts, a study was carried out to determine the horticultural adaptability and performance of 'Valencia' (*C. sinensis*) orange trees on four commercial rootstocks grown in a high-density planting on the flatwoods soil of southwest Florida.

Materials and Methods

The experiment was conducted in LaBelle, Florida to compare the effects of Swingle citrumelo [(*Citrus paradisi* (L.) × *Poncirus trifoliata* (L.) Raf.] (Swi); Cleopatra mandarin (*Citrus reshni* Hort. ex Tan.) (Cleo); Milam lemon (*C. jambhiri* hybrid or variant) (Mil); and Volkamer lemon (*C. volkameriana* Ten and Pasq.) (Volk) on leaf mineral concentration, tree growth, yield, fruit quality, and economics of 'Valencia' orange trees. The trees were planted in fall 1991 at a spacing of 19 ft between rows and 9 ft between trees at a tree density of 254 trees/acre. The trees were managed according to typical commercial practices. They were irrigated as needed using a microsprinkler irrigation system with one emitter per tree delivering 10 gal/hr. Fertilizer was applied at recommended rates for Florida citrus (Koo et al., 1984; Tucker et al., 1995) and adjusted based on leaf and soil analysis.

The soil is of the Boca series. It is loamy, siliceous, hyperthermic Arenic Ochraqualfs, poorly drained with a sandy surface, subsurface and subsoil layers to a depth of 25 to 35 inches. It is underlain by limestone and has a high water table. The organic matter content and natural fertility of the soil are low. Data were collected 4 and 7 years after planting. The experiment consisted of four treatments (rootstocks) with four replications of 4-tree plots.

Trunk circumference (C) was measured and trunk cross-sectional area (TCSA) was calculated (Zekri, 1996):

$$\text{TCSA} = C^2 / 4\ ¼$$

Tree height (H) and width in two directions parallel (W1) and perpendicular (W2) to the tree row were measured and tree canopy volume (TCV) was calculated based on the assumption that the tree shape was one half prolate spheroid (Zekri, 1996):

$$\text{TCV} = ¼/6 \times H \times W1 \times W2$$

Fruit on each tree were counted in March. Samples of sixty fruit per plot from experimental and neighboring trees were collected for fruit quality measurements and evaluations. Fruit weight, juice weight, total soluble solids or Brix and titratable acid concentrations, and juice color number were determined in the laboratory using standard procedures (Mansell, 1980). The juice was squeezed from the fruit sample and tested for Brix and acid. From these two, the Brix/acid ratio, an important flavor factor of the juice, was calculated. The Brix content (mostly soluble sugars) was determined using a hydrometer that measured the specific gravity, which was converted to degrees Brix. The percent acid was determined by titration using sodium hydroxide and a phenolphthalein indicator. For each rootstock, soluble solids/acid ratio, lb soluble solids and juice per box (90-lb-field box), average fruit weight, yield in boxes and lb solids per acre and yield efficiency were calculated (Zekri, 1996):

$$\text{Juice (lb/box)} = \frac{\text{Juice weight (lb)} \times 90\text{ lb/box}}{\text{Fruit weight (lb)}}$$

$$\text{Solids (lb/box)} = \frac{\text{Juice (lb/box)} \times \text{Brix (\%)}}{100}$$

$$\text{Yield (boxes/acre)} = \frac{\text{Fruit/tree} \times \text{Fruit wt. (oz)} \times 254\text{ trees/acre}}{16\text{ oz/lb} \times 90\text{ lb/box}}$$

$$\text{Yield (lb solids/acre)} = \text{Boxes/acre} \times \text{Solids (lb/box)}$$

$$\text{Yield efficiency (lb solids/yard}^3\text{ canopy)} = \frac{\text{Lb solids/acre}}{254\text{ trees/acre} \times \text{yard}^3\text{/tree}}$$

Expenses per acre were analyzed using cost of production or grove care and pick and haul costs. To allow production equipment to move between rows and improve light accessibility, trees on Volk were mechanically hedged and topped in 1999. Returns per acre were computed using costs of pick and haul per box, yield data, and average seasonal prices of soluble solids.

Eighty 4-6 month-old leaves per plot from non-bearing shoots were sampled in July. Leaf samples were analyzed in the laboratory using standard procedures as described in Zekri (1996). They were analyzed for nitrogen (N) by the micro-Kjeldahl method and for the other nutrients by the inductively coupled argon plasma (ICAP) spectrophotometry. With the exception of the data related to economics, statistical analysis was conducted using analysis of variance and Duncan's multiple range test was used for mean comparison when the F-test was significant at $P < 0.05$.

Results and Discussion

Leaf mineral concentration. There was no significant difference in nitrogen and phosphorus among rootstocks. However, leaf mineral concentrations of the other nutrients differed among rootstocks (Table 1). Leaf potassium concentration was significantly lower for trees on Swi and Cleo than for those on Mil and Volk. Trees on Cleo had the highest leaf Mg concentration and trees on

Table 1. Leaf mineral concentration of 'Valencia' orange trees on four rootstocks.[z]

Element	Swi	Cleo	Mil	Volk

[z]For each year, mean separation in rows by Duncan's multiple range test, 5% level.

Table 1. Leaf mineral concentration of ‘Valencia’ orange trees on four rootstocks.[z]

		1996		
Nitrogen (%)	3.15 a	3.17 a	3.19 a	3.26 a
Phosphorus (%)	0.18 a	0.19 a	0.19 a	0.19 a
Potassium (%)	1.72 b	1.66 b	2.17 a	2.28 a
Magnesium (%)	0.32 b	0.44 a	0.35 b	0.33 a
Calcium (%)	4.12 b	3.96 b	4.71 a	4.12 b
Boron (ppm)	95 a	72 b	85 a	67 b
Zinc (ppm)	65 b	161 a	188 a	177 a
Manganese (ppm)	47 b	86 a	89 a	79 a
Iron (ppm)	77 b	98 ab	105 a	99 ab
Copper (ppm)	227 b	615 a	566 a	513 a
		1999		
Nitrogen (%)	3.01 a	2.81 a	2.78 a	2.90 a
Phosphorus (%)	0.16 a	0.15 a	0.14 a	0.14 a
Potassium (%)	1.73 b	1.65 b	1.88 ab	1.96 a
Magnesium (%)	0.34 b	0.41 a	0.38 ab	0.30 c
Calcium (%)	3.17 c	3.32 c	4.46 a	4.02 b
Boron (ppm)	78 a	78 a	86 a	60 b
Zinc (ppm)	556 b	695 a	732 a	681 a
Manganese (ppm)	108 b	179 a	142 a	163 a
Iron (ppm)	73 b	104 a	100 a	102 a
Copper (ppm)	161 c	312 b	325 b	391 a

[z] For each year, mean separation in rows by Duncan’s multiple range test, 5% level.

Mil had the highest Ca concentration. Low leaf Mg concentration particularly of trees on Swi and Volk might be attributed to the translocation of Mg from leaves to satisfy fruit requirements of a relatively heavy crop for trees on those two rootstocks. Boron accumulated the least on trees on Volk. Trees on Swi accumulated the least concentration of Zn, Mn, Fe, and Cu. In flatwoods areas of southwest Florida, trees on Swi are well-known to be inefficient in taking up and accumulating micronutrients, particularly Fe (Tucker et al., 1995).

Compared to Florida citrus leaf standards (Koo et al., 1984; Tucker et al., 1995), leaf mineral concentration values were within the optimum to the high range. Differences in nutritional status among citrus rootstocks have been well-documented (Continella et al., 1988; Fallahi and Rodney, 1992; Wutscher and Shull, 1976; Zekri, 1993a, 1993b, 1995; Zekri and Parsons, 1992). Similar to this study, data collected by Wutscher and Shull (1976) showed lower leaf Mg concentration of ‘Marrs’ orange trees on Swi and Mil compared with those on Cleo. However, their data on Ca, not consistent with this study, showed that trees on Mil accumulated less Ca in their leaves than trees on Swi and Cleo. Differences in mineral concentrations among rootstocks could be attributed to the differential ability of the rootstocks to absorb water and nutrients and to the physical differences among the root systems (Zekri and Parsons, 1989). These differences can further affect growth, yield, and fruit quality of the scion cultivar.

Fruit quality. As the trees got older, there was a noticeable improvement in fruit and juice quality from all trees (Table 2). Brix, juice content, and lb solids per box were much higher in 1999 than in 1996 for trees on all rootstocks. Internal qualities of fruit from trees on Swi were superior to those from trees on Mil and Volk. Percent Brix, Brix/acid ratio, lb solids and juice per box were all significantly higher for trees on Swi than with those on the lemon rootstocks. However, no significant differences were detected in juice content and total soluble solids in the fruit of trees on Swi, Cleo, and Mil (Wutscher and Shull, 1976). The Brix levels in fruit from 14-year old ‘Ambersweet’ trees on Cleo, sour orange, and Carrizo citrange were found very similar, but higher than those from trees on rough lemon rootstock (Hearn, 1989). For ‘Valencia’ orange, soluble solids in the juice were found to be higher on Swi than Mil (Wheaton et al., 1991). Other workers also found that fruit quality of citrus scion cultivars was affected by rootstocks (Castle and Phillips, 1980; Continella et al., 1988; Economides and Gregorian, 1993; Fallahi and Rodney, 1992; Fallahi et al., 1989; Gardner and Horanic, 1961, 1966; Zekri, 1996).

Table 2. Fruit quality of ‘Valencia’ trees on four rootstocks.[z]

Variable	Swi	Cleo	Mil	Volk
		1996		
Brix (%)	10.10 a	9.25 b	8.65 c	8.30 c
Acid (%)	0.90 a	0.90 a	0.83 b	0.79 b
Ratio	11.22 a	10.28 b	10.42 b	10.51 b
Juice (lb/box)	50.70 a	50.14 ab	49.92 ab	48.77 b
Solids (lb/box)	5.12 a	4.64 b	4.32 bc	4.05 c
Color number	37.20 a	36.70 a	36.70 a	36.40 a
		1999		
Brix (%)	12.37 a	12.46 a	11.13 b	10.87 b
Acid (%)	0.69 b	0.86 a	0.69 b	0.74 b
Ratio	17.93 a	14.49 c	16.13 b	14.69 c
Juice (lb/box)	53.80 a	53.97 a	51.22 b	51.76 b
Solids (lb/box)	6.66 a	6.72 a	5.70 b	5.63 b

[z] For each year, mean separation in rows by Duncan’s multiple range test, 5% level.

In Florida, Brix and Brix:acid ratio are the main factors used in judging fruit maturity. The higher the Brix and the Brix:acid ratio, the earlier is the fruit maturity. According to this, Swi promoted earlier maturity of ‘Valencia’ orange than the other rootstocks. This is a very important advantage of Swi over the other rootstocks, particularly for the fresh fruit market. Usually, the earlier the fruit reaches the market, the higher is the return.

A juice color number or score of 36 minimum is necessary for Grade A orange juice, and 32 to 35 is needed for Grade B juice (Stewart, 1980). Early in the season, the juice from four-year-old ‘Valencia’ orange trees met the minimum color score of 36 needed to make Grade A orange juice (Table 2). The juice color number of fruit from these trees ranged from 36.40 for Volk to 37.20 for Swi. In this study, the juice color was not found to be significantly affected by rootstocks. However, in another study, juice color number or score of ‘Ambersweet’ orange was found higher for trees on Swi than for trees on Cleo (Zekri, 1996).

Tree size and growth. Trunk cross sectional area (TCSA) and tree canopy volume (TCV) of trees grown on Volk were greater than those on Swi, Cleo, and Mil rootstocks (Table 3). In this study, trees on Cleo were damaged very severely by phytophthora foot and root rot which reduced growth and tree size. In 1996, trees on Swi had larger canopy than those on Mil. In 1999, trees on Mil were similar to the size of trees on Swi. At 7 yrs of age, canopy size of ‘Valencia’ trees on Swi was also found to be larger than those of trees growing on Mil and Cleo (Wheaton et al., 1991). However,

Table 3. Trunk cross sectional area (TCSA), tree canopy volume (TCV), fruit weight, yield, and yield efficiency (YE) of ‘Valencia’ orange trees on four rootstocks.[z]

Variable	Swi	Cleo	Mil	Volk

[z] For each year, mean separation in rows by Duncan’s multiple range test, 5% level.

Table 3. Trunk cross sectional area (TCSA), tree canopy volume (TCV), fruit weight, yield, and yield efficiency (YE) of 'Valencia' orange trees on four rootstocks.[z]

		1996		
TCSA (inch^2)	7.96 b	5.54 c	7.71 b	13.03 a
TCV (yard^3)	15.25 b	6.99 c	9.20 c	22.76 a
Fruit wt (oz)	7.86 b	6.62 c	7.66 b	8.51 a
Fruit/tree	124.80 b	12.00 d	55.63 c	142.00 a
Yield (box/acre)	173.02 b	14.01 d	75.16 c	213.15 a
Yield (lb solids/acre)	885.86 a	65.01 c	324.69 b	863.26 a
YE (lb solids/yard^3)	0.23 a	0.04 c	0.14 b	0.15 b
		1999		
TCSA (inch^2)	13.43 b	12.73 b	17.11 b	33.35 a
TCV (yard^3)	21.27 b	15.90 c	21.35 b	33.46 a
Fruit wt (oz)	7.75 b	7.70 b	9.14 a	9.20 a
Fruit/tree	187.80 a	79.17 c	137.60 b	198.33 a
Yield (box/acre)	256.73 b	107.53 c	221.84 b	321.85 a
Yield (lb solids/acre)	1709.82 a	722.60 c	1264.49 b	1812.02 a
YE (lb solids/yard^3)	0.32 a	0.18 b	0.23 b	0.21 b

[z] For each year, mean separation in rows by Duncan's multiple range test, 5% level.

canopy sizes of 'Minneola' tangelo, 'Olinda Valencia', 'Washington' navel (Roose et al., 1989) and 'Valencia' (Monteverde et al., 1988) trees on Swi were found similar to those on Cleo. Furthermore, TCSA of 'Marsh' (Economides and Gregoriou, 1993) and TCV and TCSA of 'Redblush' (Fallahi et al., 1989) grapefruit trees were found to be higher on Cleo than on Swi.

Fruit size. In 1996, fruit from trees on Volk were the largest and heaviest (Table 3). In 1999, fruit from trees on both lemon rootstocks, Volk and Mil, were significantly larger and heavier than those from trees on Swi and Cleo. Visually, fruit from trees on Volk and Mil had thicker and coarser peel and were greener than fruit from trees on Swi and Cleo. Peel thickness and texture were similar between fruit from trees on Swi and Cleo. Fallahi et al. (1989) and Monteverde et al. (1988) also found similar fruit rind thickness of fruit from trees on Swi and Cleo. Fruit weight and size in the present study were consistent with those of Economides and Gregoriou (1993), Fallahi et al. (1989) and Monteverde et al. (1988) which did not detect significant differences between trees on Swi and those on Cleo.

Fruit size from trees on Cleo were at best similar to that from trees on Swi (Table 3). These results agreed with those of Rouse and Maxwell (1979) and with Wutscher and Shull (1976) which showed larger fruit size for trees grown on Swi as compared with trees on Cleo. However, in another study with 'Ambersweet' orange (Zekri, 1996, 1997), fruit produced on Cleo were larger than fruit produced on Swi. This conflict between results could be attributed to tree age, canopy size, and fruit number per tree. In general, fruit size is negatively correlated with fruit number per tree. The fewer the fruit on the tree, the larger and heavier are the fruit. However, in this study, fruit size differences among trees on different rootstocks were not attributed to crop load. Trees on Volk had the highest number of fruit per trees and the largest fruit size.

Fruit yield. In 1996, trees on Volk produced the most fruit per tree and the highest yield in terms of boxes per acre (Table 3). However, the yield expressed in terms of lb solids per acre was not significant between Volk and Swi. The lack of significance is attributed to the relatively higher percent Brix, and lb juice and solids per box for the fruit from trees on Swi compared with those on Volk. In 1999, fruit per tree and yield expressed in lb solids per acre were also significantly lower for Cleo and Mil than for Swi and Volk. The number of fruit per tree and yield (lb solids/acre) of trees on Swi and Volk were similar. The poor crop for trees on Cleo was partly attributed to the Phytophthora infestation which also reduced tree growth and tree size. Although the yield (lb solids/acre) increased by over ten-fold for trees on Cleo from 1996 to 1999, it was less than half of the yield recorded for trees on Volk and Swi. Trees on Cleo grew and fruited poorly during these first few years. This was consistent with Gardner and Horanic (1961) who concluded that scions on Cleo were not precocious. Similar results of yield problems for trees on Cleo have been found from many citrus areas inside and outside Florida. Cleo is considered a "lazy" rootstock because trees onto it fruit relatively poorly until they are 10 to 15 yrs of age (Castle et al., 1993).

Cumulative yield from age 5 to 8 yrs of 'Valencia' trees on Swi were higher than those on Mil and Cleo (Wheaton et al., 1991). Higher yields of trees on Swi than on Cleo were also found for 'Marrs' orange (Wutscher and Shull, 1976), 'Ambersweet' orange (Zekri, 1996, 1997), 'Marsh' grapefruit (Economides and Gregoriou, 1993), 'Minneola' tangelo (Roose et al., 1989) and 'Redblush' grapefruit (Rouse and Maxwell, 1979). However, no differences in yield between trees on Swi and Cleo were reported for 'Redblush' grapefruit (Fallahi et al., 1989), 'Valencia' orange (Monteverde et al., 1988) and 'Olinda Valencia' and 'Washington' navel (Roose et al., 1989). All these results indicated the inconsistency in yield differences as affected by rootstocks, which could be attributed to differences in scion cultivars, tree age, climatic conditions, and soil characteristics.

Yield efficiency. Yield efficiency (YE) expressed as lb solids per cubic yard of canopy varied among rootstocks (Table 3). Trees on Swi had the highest yield efficiency. Although trees on Swi and Volk had similar yield, yield efficiency was higher for trees on Swi than for those on Volk because of the relatively smaller canopy size of trees on Swi. High YE combined with small tree size makes Swi a very attractive rootstock for high-density plantings. These results agreed with earlier reports of higher YE, expressed as lb fruit per unit of TCV and/or TCSA of grapefruit (Economides and Gregoriou, 1993; Fallahi et al., 1989), 'Ambersweet' orange (Zekri, 1996, 1997) and tangelo and 'Olinda Valencia' (Roose et al., 1989) on Swi as compared with trees on other rootstocks. However, no significant difference in YE was found between those on Swi and Cleo with 'Valencia' (Monteverde et al., 1988) and 'Washington' navel (Roose et al., 1989) because of the lack in differences in yield and canopy sizes between the two rootstocks.

Economics. Production costs were estimated at $700/acre. In 1999, production costs for trees on Volk were at $750/acre, which included hedging and topping expenses of $50/acre. Costs of pick and haul per box were estimated at $1.80. Prices of soluble solids per lb were estimated at $1.30 and $1.20 in 1996 and 1999, respectively. Financial analysis showed a negative balance in 1996 for trees on Cleo and Mil and in 1999 for trees on Cleo (Table 4). Four and seven years after planting, 'Valencia' orange trees on Swi gave the highest profits. These results revealed the financial advantage of Swi over the other rootstocks when the trees were planted in a closely spaced setting. The early yield and high return of trees on Swi compared with trees on the other rootstocks are advantageous for citrus growers in southwest Florida.

Conclusions

Rootstocks can affect the success and profitability of virtually any commercial citrus culture. Rootstock use is considered essential in citriculture because of its strong influence on how and where successfully citrus can be grown. Furthermore, tree vigor must be

Table 4. Financial analysis of 'Valencia' orange trees on four rootstocks.

	($/acre)			
Variable	Swi	Cleo	Mil	Volk
		1996		
Production costs	700.00	700.00	700.00	700.00
Pick and haul[z]	311.44	25.22	135.29	383.67
Total expenses	1011.44	725.22	835.29	1083.67
Revenue[y]	1151.62	84.51	422.10	1122.23
Balance (+/-)	+140.18	-640.71	-413.19	+38.56
		1999		
Production costs	700.00	700.00	700.00	750.00[x]
Pick and haul	462.11	193.55	399.31	579.33
Total expenses	1162.11	893.55	1099.31	1329.33
Revenue	2051.78	867.12	1517.39	2174.42
Balance (+/-)	+889.67	-26.43	+418.08	+845.09

[z] Pick and haul costs are based on $1.80/box.

[y] Revenue is based on $1.30 and $1.20/lb solids of Valencia oranges for 1996 and 1999, respectively.

[x] Production costs include $50/acre for hedging and topping expenses for Volk.

included in making a decision about selecting tree spacing. At high-density planting, 'Valencia' orange trees performed the best on Swi as compared with Cleo, Mil, or Volk rootstocks. Trees on Swi were more precocious and more yield efficient than those on the other rootstocks. Special care should be taken when planting trees on Cleo on southwest Florida flatwoods soils because of Cleo's high susceptibility to Phytophthora. Growing trees on Volk, a vigorous rootstock, at relatively high-density, is not a good strategy because trees on this rootstock quickly reach their containment size and need to be hedged and topped at relatively young age.

Based on this study, Swi is a good choice as a rootstock for 'Valencia' orange in southwest Florida due to its high fruit and juice quality, yield, yield efficiency, and profit. The results obtained from this and similar studies demonstrate the feasibility of high-density planting for Florida citrus and show that selection of appropriate rootstocks is a very important component in the success of such a planting. Although trees on Volk produced very well, confining tree size to the allocated space over a long period would be a difficult task, expensive, and will reduce yield and yield efficiency. The poor performance of Cleo as a rootstock for 'Valencia' orange was further aggravated by its high susceptibility to Phytophthora in poorly drained situations on the flatwoods. This study is still in progress to find out for how long this trend will hold. The early yield and return of Swi still remain an important advantage, particularly over Cleo and Mil although fruit production, efficiency, and quality of trees on these rootstocks may improve as the trees get older.

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