Original article

Citrus rootstocks affect scion nutrition, fruit quality, growth, yield and economical return

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Citrus rootstocks affect scion nutrition, fruit quality, growth, yield and economical return.

Abstract — **Introduction**. Since the environmental conditions and cultural practices are unique in southwest Florida, a study was carried out to determine the horticultural adaptability and performance of 'Valencia' orange trees on four commercial rootstocks grown in a high-density planting. **Materials and methods**. The trees were planted in 1991 on a flatwoods soil in a commercial grove at a density of 627 trees·ha^{-1}. Leaf mineral concentration, growth, fruit production and quality were measured 4 and 7 years after planting. **Results**. Compared to Florida citrus leaf standards, leaf mineral concentration values were within the optimum to the high range. Yield efficiency expressed as kg solids·m^{-3} of canopy and juice quality in terms of juice content, Brix, and kg solids·box^{-1} increased with tree age. Trees on Volkamer lemon (Volk) had the largest canopy and fruit size, while those on Cleopatra mandarin (Cleo) had the smallest. Fruit yield was the highest for trees on Volk. However, yield expressed in kg solids·ha^{-1} was not significantly different between trees on Volk and those on Swingle citrumelo (Swi) due to the higher solids·box^{-1} for trees on Swi. Yield efficiency was also higher for trees on Swi than for those on Volk. Juice content and soluble solids in the fruit were higher for trees on Swi and Cleo than for those on the lemon rootstocks. Financial analysis showed that, at high density planting, trees on Swi were the most profitable. **Conclusion**. On non-calcareous flatwoods soil, Swi is the best suited rootstock for high-density planting. © Éditions scientifiques et médicales Elsevier SAS

USA / Florida / *Citrus sinensis* / rootstocks / rootstock scion relationships / quality / fruit / growth / yields / economic analysis

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L'effet du porte-greffe des agrumes sur la nutrition du scion, la qualité du fruit, la croissance, le rendement et les retombées économiques.

Résumé — **Introduction**. Les conditions d'environnement et les méthodes culturales étant spécifiques dans le sud-ouest de la Floride, une étude a été effectuée pour déterminer les potentiels d'adaptation et de rendement d'orangers cv. Valencia greffés sur quatre porte-greffes commerciaux plantés à haute densité. **Matériel et méthodes**. Les arbres ont été plantés en 1991 sur un sol de bas-fonds, dans une plantation commerciale à 627 arbres·ha^{-1}. La teneur en éléments minéraux des feuilles, la croissance, la production et la qualité des fruits ont été mesurées 4 et 7 ans après plantation. **Résultats**. Par rapport aux normes établies en Floride, les teneurs en éléments minéraux des feuilles ont été parmi les plus fortes observées jusqu'à présent. Le rendement, en kg fruits·m^{-3} de canopie, et la qualité du jus exprimée en teneur du fruit, Brix, et kg·caisse^{-1} a augmenté avec l'âge de l'arbre. Les arbres greffés sur citronnier Volkamer (Volk) ont eu la canopie la plus développée et les fruits les plus gros, alors que ceux sur mandarine Cleopatra (Cleo) ont donné les moindres résultats. Les rendements en fruits ont été les plus forts sur Volk, alors que ceux exprimé en kg solides·ha^{-1} ont été analogues pour les agrumes greffés sur Volk et ceux sur citrumelo Swingle (Swi) du fait de plus fortes valeurs de solides·caisse^{-1} obtenues pour les arbres sur Swi. Le rendement en kg solides·m^{-3} de canopie a été plus fort pour les arbres sur Swi que pour ceux sur Volk. La teneur en jus et en solides solubles du fruit ont été plus élevés pour des arbres sur Swi et Cleo que pour ceux sur Volk. L'analyse financière a montré qu'à haute densité de plantation les orangers greffés sur Swi étaient les plus intéressants. **Conclusion**. Sur sol non-calcaire de bas-fonds, le porte-greffe le mieux adapté en plantation à haute densité serait le cv. Swingle. © Éditions scientifiques et médicales Elsevier SAS

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1. introduction

Citrus is of major economic importance in many counties of Florida, exceeding \$8 billion a year in the state. In Florida, citrus groves occupy over 845 thousand acres with over 107 million trees [1]. Prior to 1970, rough lemon and sour orange were the most common rootstocks in Florida. Rootstocks have become a more critical issue in the last 30 years largely because of blight and the increased incidence of tristeza and frequency of freezes [2]. 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 [3]. 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 [4].

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 [5–19]. 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 (flatwoods) 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' orange trees on four commercial rootstocks grown in a high-density planting on the flatwoods soil of southwest Florida.

2. 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. volkamerian* Ten and Pasq.) (Volk) on leaf mineral concentrations, tree growth, yield, fruit quality, and economics of 'Valencia' orange trees.

The trees were planted in fall 1991 at a spacing of 2.75 m between trees and 5.80 m between rows at a tree density of 627 trees·ha^{-1}. 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 40 L·h^{-1}. Fertilizer was applied at recommended rates for Florida citrus [20, 21] and adjusted based on leaf and soil analysis.

The soil was a Boca sand, poorly drained, with a sandy surface, subsurface and subsoil layers to a depth of 60 to 90 cm. It was underlain by limestone and had a high water table. The organic matter content and natural fertility of the soil were low. The soil pH was 6.8–7.1, and the cation exchange capacity was 3.5–3.9 mEq·100 g^{-1}. Data were collected 4 and 7 years after planting. The experiment was a randomized complete block design with four treatments (rootstocks) and four replications of four-tree plots.

Trunk circumference (Tc) was measured and trunk cross-sectional area (Tcsa) was calculated: $Tcsa = Tc^2 / 4 \Pi$.

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:

$$Tcv = \Pi/6 \times h \times w1 \times w2.$$

Fruit on each tree were counted in March. Samples of 60 fruit per plot from experimental and adjacent trees were collected for fruit quality measurements and evaluations. Fruit weight, juice weight, total soluble solids (TSS) or Brix and titratable acid (TA) concentrations, and juice color number were determined in the laboratory using standard procedures [22]. The juice was squeezed from the fruit sample and the juice was tested for Brix and acid. From these two parameters, the [TSS/TA] ratio, an important quality attribute of the juice, was calculated. The Brix content (TSS) 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, [TSS/TA] ratio, soluble solids weight (in kg) and juice per box (40.8-kg field box), average fruit weight, yield in boxes and kg solids per ha and yield efficiency were calculated:

Juice ($kg \cdot box^{-1}$) = [Juice weight (kg) $\times$ 40.8 $kg \cdot box^{-1}$] / Fruit weight (kg)

Solids ($kg \cdot box^{-1}$) = [Juice ($kg \cdot box^{-1}$) $\times$ Brix (%)] / 100

Yield ($boxes \cdot ha^{-1}$) = [$Fruit \cdot tree^{-1}$ $\times$ Fruit weight (g) $\times$ 627 $trees \cdot ha^{-1}$] / [1 000 $g \cdot kg^{-1}$ $\times$ 40.8 $kg \cdot box^{-1}$]

Yield (kg $solids \cdot ha^{-1}$) = $Boxes \cdot ha^{-1}$ $\times$ Solids ($kg \cdot box^{-1}$)

Yield efficiency (kg $solids \cdot m^{-3}$ canopy) = kg $solids \cdot ha^{-1}$ / 627 $trees \cdot ha^{-1} \times m^3 \cdot tree^{-1}$

Expenses per ha were analyzed using cost of production or grove care and pick and haul. To allow production equipment to move between rows and improve light accessibility, trees on Volk were mechanically hedged and topped in 1999 for $\$123.50 \cdot ha^{-1}$. Costs of pick and haul per box were estimated at $1.80. Returns per ha were computed using yield data and average seasonal prices of soluble solids. Prices of soluble solids per kg were estimated at $2.87 and $2.65 in 1996 and 1999, respectively.

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. They were analyzed for nitrogen (N) by the micro-Kjeldahl method and for the other nutrients by an inductively coupled argon plasma (ICAP) spectrophotometer. 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 $p < 0.05$.

3. results and discussion

Effects of rootstocks on leaf mineral concentration, growth, yield, fruit size, and/or quality of citrus scion cultivars have been reported [5–16, 18, 19].

3.1. leaf mineral concentration

Compared to Florida citrus leaf standards [20, 21], leaf mineral concentration values were within the optimum to the high range (*table I*). There was no significant difference in nitrogen (N) and phosphorus (P) among rootstocks. Leaf potassium (K) concentration was significantly lower for trees on Swi and Cleo than for those on Mil and Volk. Trees on Cleo had the highest leaf magnesium (Mg) concentration and trees on Mil had the highest calcium (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 (B) was accumulated the least on trees on Volk. Trees on Swi accumulated the least concentration of zinc (Zn), manganese (Mn), iron (Fe), and copper (Cu). In flatwoods areas of southwest Florida, trees on Swi are well-known to be inefficient in taking up and accumulating micronutrients, particularly Fe [21].

Differences in nutritional status among citrus rootstocks have been well-documented [6, 9, 17, 23–26]. Similar to this study, data collected by Wutscher and Shull [17] 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 the results of 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 [27]. These differences can further affect growth, yield, and fruit quality of the scion cultivar.

Table I.
Leaf mineral concentration of 'Valencia' orange trees on four citrus rootstocks in Florida.

Rootstock[1]	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Magnesium (%)	Calcium (%)	Boron (µg·g⁻¹)	Zinc (µg·g⁻¹)	Manganese (µg·g⁻¹)	Iron (µg·g⁻¹)	Copper (µg·g⁻¹)
1996										
Swi	3.15	0.18	1.72 b	0.32 b	4.12 b	95 a	65 b	47 b	77 b	227 b
Cleo	3.17	0.19	1.66 b	0.44 a	3.96 b	72 b	161 a	86 a	98 ab	615 a
Mil	3.19	0.19	2.17 a	0.35 b	4.71 a	85 a	188 a	89 a	105 a	566 a
Volk	3.26	0.19	2.28 a	0.33 b	4.12 b	67 b	177 a	79 a	99 ab	513 a
Significance	ns	ns	**	**	**	**	**	**	**	**
1999										
Swi	3.01	0.16	1.73 b	0.34 b	3.17 c	78 a	556 b	108 b	73 b	161 c
Cleo	2.81	0.15	1.65 b	0.41 a	3.32 c	78 a	695 a	179 a	104 a	312 b
Mil	2.78	0.14	1.88 ab	0.38 ab	4.46 a	86 a	732 a	142 a	100 a	325 b
Volk	2.90	0.14	1.96 a	0.30 c	4.02 b	60 b	681 a	163 a	102 a	391 a
Significance	ns	ns	**	**	**	**	**	**	**	**

For each year, within a column, means followed by a same letter are not significantly different according to Duncan's multiple range test ($p = 0.05$); ns: not significant means.
[1] Swi, Swingle citrumelo; Cleo, Cleopatra mandarin; Mil, Milam lemon; Volk, Volkamer lemon.

3.2. fruit quality

As the trees became older, there was a noticeable improvement in fruit and juice quality from all trees (*table II*). Brix, juice content, and kg 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, kg solids and juice per box were all significantly higher for trees on Swi than for trees on the lemon rootstocks. However, no significant differences were detected in juice content and TSS in the fruit of trees on Swi, Cleo, and Mil [17]. 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 [28]. For 'Valencia' orange, soluble solids in the juice were found higher on Swi than on Mil [16]. Other workers also found that fruit quality of citrus scion cultivars was affected by rootstocks [5–11, 18, 19].

In Florida, Brix and [Brix/acid] ratio are the main factors 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 [29]. Early in the season, the juice from 4-year-old 'Valencia' orange trees has met the minimum color score of 36 needed to make grade A orange juice (*table II*). 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 [18, 19].

3.3. 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 III*). In this study, trees on Cleo were damaged very

Table II.
Fruit quality of 'Valencia' trees on four citrus rootstocks in Florida.

Rootstock[1]	Brix (%)	Acid (%)	Ratio [Brix/acid]	Juice ($kg \cdot box^{-1}$)	Solids ($kg \cdot box^{-1}$)	Color number
1996						
Swi	10.10 a	0.90 a	11.22 a	23.00 a	2.32 a	37.20
Cleo	9.25 b	0.90 a	10.28 b	22.74 ab	2.10 b	36.70
Mil	8.65 c	0.83 b	10.42 b	22.64 ab	1.96 bc	36.60
Volk	8.30 c	0.79 b	10.51 b	22.12 b	1.84 c	36.40
Significance	**	**	**	**	**	ns
1999						
Swi	12.37 a	0.69 b	17.93 a	24.40 a	3.02 a	–
Cleo	12.46 a	0.86 a	14.49 c	24.48 a	3.05 a	–
Mil	11.13 b	0.69 b	16.13 b	23.23 b	2.59 b	–
Volk	10.87 b	0.74 b	14.69 c	23.48 b	2.55 b	–
Significance	**	**	**	**	**	–

For each year, within a column, means followed by a same letter are not significantly different according to Duncan's multiple range test ($p = 0.05$); ns: not significant means.
[1] Swi, Swingle citrumelo; Cleo, Cleopatra mandarin; Mil, Milam lemon; Volk, Volkamer lemon.

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 able to reach the size of trees on Swi. At 7 years of age, canopy size of 'Valencia' trees on Swi was also found to be larger than those of trees growing on Mil and Cleo [16]. However, canopy sizes of 'Minneola' tangelo, 'Olinda Valencia', 'Washington' navel [14] and 'Valencia' [13] trees on Swi were found similar to those on Cleo. Furthermore, Tcsa of 'Marsh' [7] and Tcv and Tcsa of 'Redblush' [8] grapefruit trees were found to be higher on Cleo than on Swi.

3.4. fruit size

In 1996, fruit from trees on Volk were the heaviest (*table III*). 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. [8] and Monteverde et al. [13] 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 [7], Fallahi et al. [8] and Monteverde et al. [13], who did not detect significant differences between trees on Swi and those on Cleo.

Fruit size from trees on Cleo was at best similar to that from trees on Swi (*table III*). These results agreed with those of Rouse and Maxwell [15] and Wutscher and Shull [17] which showed larger fruit size for trees grown on Swi as compared with trees on Cleo. However, in another study with 'Ambersweet' orange [18, 19], 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.

Table III.
Trunk cross–sectional area (Tcsa), tree canopy volume (Tcv), fruit weight, yield, and yield efficiency (YE) of 'Valencia' orange trees on four citrus rootstocks in Florida.

Rootstock[1]	Tcsa (cm^2)	Tcv (m^3)	Fruit weight (g)	Fruit/tree	Yield ($box \cdot ha^{-1}$)	Yield ($kg\ solids \cdot ha^{-1}$)	YE ($kg\ solids \cdot m^{-3}$)
1996							
Swi	51.36 b	11.66 b	222.83 b	124.80 b	427.36 b	992.51 a	0.14 a
Cleo	35.74 c	5.34 c	187.68 c	12.00 d	34.60 d	72.84 c	0.02 c
Mil	49.74 b	7.03 c	217.16 b	55.63 c	185.65 c	363.78 b	0.08 b
Volk	84.07 a	17.40 a	241.26 a	142.00 a	526.48 a	967.19 a	0.09 b
Significance	**	**	**	**	**	**	**
1999							
Swi	86.65 b	16.26 b	219.71 b	187.80 a	634.12 b	1915.67 a	0.19 a
Cleo	82.13 b	12.16 c	218.30 b	79.17 c	265.60 c	809.60 c	0.11 b
Mil	110.39 b	16.32 b	259.12 a	137.60 b	547.94 b	1416.72 b	0.14 b
Volk	215.17 a	25.58 a	260.82 a	198.33 a	794.97 a	2030.17 a	0.13 b
Significance	**	**	**	**	**	**	**

For each year, within a column, means followed by a same letter are not significantly different according to Duncan's multiple range test ($p = 0.05$); ns: not significant means.
[1] Swi, Swingle citrumelo; Cleo, Cleopatra mandarin; Mil, Milam lemon; Volk, Volkamer lemon.

3.5. fruit yield

In 1996, trees on Volk produced the most fruit per tree and the highest yield in terms of boxes per ha (*table III*). However, the yield expressed in terms of kg solids per ha was not significant between Volk and Swi. The lack of significance is attributed to the relatively higher percent Brix and kg 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 kg solids per ha were also significantly lower for Cleo and Mil than for Swi and Volk. The number of fruit per tree and yield ($kg\ solids \cdot ha^{-1}$) 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 ($kg\ solids \cdot ha^{-1}$) 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 had poor growth and production during these first few years. This was consistent with Gardner and Horanic [10] 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 on it fruit relatively poorly until they are 10 to 15 years of age [2].

Cumulative yield from age 5 to 8 years of 'Valencia' trees on Swi was higher than that of trees on Mil and Cleo [16]. Higher yields of trees on Swi than on Cleo were also found for 'Marrs' orange [17], 'Ambersweet' orange [18, 19], 'Marsh' grapefruit [7], 'Minneola' tangelo [14] and 'Redblush' grapefruit [15]. However, no differences in yield between trees on Swi and Cleo were reported for 'Redblush' grapefruit [8], 'Valencia' orange [13], and 'Olinda Valencia' and 'Washington' navel [14]. 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.

3.6. yield efficiency

Yield efficiency (YE) expressed as kg solids per cubic meter of canopy varied among rootstocks (*table III*). 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 trees 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 kg fruit per unit of Tcv and/or Tcsa of grapefruit [7, 8], 'Ambersweet' orange [18, 19] and tangelo and 'Olinda Valencia' [14] on Swi as compared with trees on other rootstocks. However, no significant difference in YE was found between Swi and Cleo with 'Valencia' [13] and 'Washington' navel [14] because of the lack of differences in yield and canopy sizes between trees on the two rootstocks.

3.7. economics

Financial analysis showed a negative balance in 1996 for trees on Cleo and Mil and, in 1999, for trees on Cleo (*table IV*). 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.

4. conclusion

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 citrus can be successfully grown. Furthermore, tree vigor must be included in making a decision about selecting tree spacing. At high-density planting, 'Valencia' orange trees performed better on Swi than on 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 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 a relatively young age.

Based on this study, Swi is a good choice as a rootstock for 'Valencia' orange in south-

Table IV.
Financial analysis ($US) of the production of 'Valencia' orange trees grafted on four citrus rootstocks in Florida.

Rootstock[1]	Production costs[2]	Pick and haul[3]	Total expenses	Revenue[4]	Balance (+/–)
1996					
Swi	1729.00	769.25	2498.25	2848.50	+350.25
Cleo	1729.00	62.28	1791.28	209.05	–1582.23
Mil	1729.00	334.17	2063.17	1044.05	–1019.12
Volk	1729.00	947.66	2676.66	2775.84	+99.18
1999					
Swi	1729.00	1141.42	2870.42	5076.53	2206.11
Cleo	1729.00	478.08	2207.08	2145.44	–61.64
Mil	1729.00	986.29	2715.29	3754.31	1039.02
Volk	1852.50*	1430.95	3283.45	5379.95	2096.50

[1] Swi, Swingle citrumelo; Cleo, Cleopatra mandarin; Mil, Milam lemon; Volk, Volkamer lemon.
[2] Production costs include $123.50·ha^{-1} for hedging and topping expenses for Volk.
[3] Pick and haul costs are based on $1.80 per box.
[4] Revenue is based on $2.87 and $2.65·kg^{-1} solids of Valencia oranges for 1996 and 1999, respectively.

west 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 with age.

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El efecto del portainjerto de los agrios en el nutrimiento de la púa, la calidad del fruto, el crecimiento, el rendimiento y las consecuencias económicas.

Resumen — **Introducción**. Las condiciones atmosféricas y los métodos de cultivo, siendo específicos en el sudoeste de Florida, se ha ejecutado un estudio para determinar los potenciales de adaptación y de rendimiento del naranjo 'Valencia', en cuatro portainjertos comerciales plantados en alta dehsidad. **Material y métodos**. Los árboles se plantaron en 1991 en un suelo de bajo fondo en una plantación comercial que contenía 627 árboles·ha^{-1}. Cuatro y siete años después de la plantación, se midieron el contenido en elementos minerales de las hojas, el crecimiento, la producción y la calidad de frutas. **Resultados**. Con respecto a las normas establecidas en Florida, los contenidos en elementos minerales de las hojas han sido uno de los más altos observados hasta ahora. El rendimiento en kg de frutas·m^{-3} de follaje y la calidad del jugo exprimido en contenido de la fruta, Brix, y en kg·caja^{-1}, ha aumentado con la edad del árbol. Los árboles injertados sobre el limonero Volkamer (Volk) han tenido el follaje más desarrollad y las frutas más grandes, mientras que aquellos injertados sobre la mandarina Cleopatra (Cleo) han dado bastante peores resultados. En lo referido a las frutas, los rendimientos más fuertes han sido con Volk, mientras que los rendimientos en kg sólidos·ha^{-1} han sido similares para los agrios injertados sobre Volk que para aquellos injertados sobre citrumelo Swingle (Swi) a raíz de la superioridad de los valores obtenidos en sólidos·caja^{-1} por los injertos sobre Swi. El rendimiento en kg sólidos·m^{-3} de follaje ha sido más alto para los árboles sobre Swi que para aquellos sobre Volk. El contenido en jugo y en sólidos solubles de frutas ha sido más alto para los árboles sobre Swi y Cleo, que para aquellos sobre Volk. El análisis financiero ha mostrado que, a altas densidades de plantación, los agrios sobre Swi eran los más interesantes. **Conclusión**. En un suelo no calcario de bajo fondo, el portainjerto mejor adaptado en una plantación de alta densidad sería el cultivar Swingle. © Éditions scientifiques et médicales Elsevier SAS

Eua / Florida / *Citrus sinensis* / portainjertos / relación es patrón injerto / calidad / fruto / crecimiento / rendimiento / análisis económico