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Evaluation of 'Arrayana' tangerine (*Citrus reticulata* Blanco) grafted onto different rootstocks in tropical lowlands of Colombian Orinoquia, 2005-2011 (second cycle)

Evaluación de la mandarina 'Arrayana' (*Citrus reticulata* Blanco) injertada en diferentes patrones en el trópico bajo de la Orinoquia colombiana, 2005-2011 (segundo ciclo)

Hans Nicolás Chaparro-Zambrano¹, Heberth Augusto Velásquez-Ramírez², and Javier Orlando Ordúz-Rodríguez²

ABSTRACT

'Arrayana' tangerine (*Citrus reticulata* Blanco) is the most cultivated variety in Meta piedmont; it is mainly grafted onto the 'Cleopatra' tangerine rootstock (*Citrus reshni* hort. ex Tanaka). Plants grafted onto this rootstock have a late production entrance, produce big plants and their yield is affected by the rainfall patterns that occur during the dry season. Five rootstocks were evaluated to identify the one with the best productive performance for 'Arrayana' tangerine. The experiment was established in 1997. The report of the first five harvest was published in 2006. This report shows the results of six additional pickings. The rootstocks with the highest yields were citrumelo 'Swingle' (CPB 4475) and Sunki × English (S×E), without statistical differences, followed by Sunki × Jacobson (S×J) (no statistical differences with S×E), 'Cleopatra' and 'Volkamer'. The lowest yield was obtained from 'Carrizo'. Citrumelo 'Swingle', S×E, S×J and 'Volkamer' obtained plants of 'Arrayana' tangerine with less height and volume than 'Cleopatra'; the best productive efficiency was obtained by S×J followed by citrumelo 'Swingle', S×E (no statistical differences) markedly higher than 'Cleopatra' and 'Carrizo'. Citrumelo 'Swingle' produced 2,438 kg/plant in 11 pickings overpassing S×E by 1,776.6 kg of fruit per plant, 'Volkamer' (1,572.99 kg/plant) and S×J (1,498.95 kg/plant). Citrumelo 'Swingle' outyielded 'Cleopatra' by more than 1 t per tree in cumulative yield of 11 pickings. All rootstocks showed good fruit quality for domestic market.

Key words: citriculture, growth, production, fruit quality, genotype.

RESUMEN

La mandarina 'Arrayana' (*Citrus reticulata* Blanco) es la variedad más cultivada en el piedemonte llanero de Colombia. El patrón utilizado para su cultivo es la mandarina 'Cleopatra' (*Citrus reshni* hort. ex Tanaka). Este patrón es de tardía entrada en producción, produce árboles de gran tamaño y la precipitación en la época seca afecta su rendimiento. Con el propósito de identificar patrones de mejor comportamiento productivo se evaluaron cinco patrones utilizados en la citricultura colombiana. El experimento se estableció en 1997. El reporte sobre las cinco primeras cosechas se publicó en el año 2006. Este artículo presenta los resultados de seis cosechas adicionales. El patrón con mayor producción acumulada fue citrumelo 'Swingle' y Sunki × English (S×E) sin diferencias estadísticas seguido por Sunki × Jacobson (sin diferencias estadísticas con S×E), 'Cleopatra' y 'Volkameriana'. El último lugar en producción estuvo el patrón 'Carrizo'. Citrumelo 'Swingle', S×E, S×J y 'Volkameriana' formaron plantas de menor altura y volumen de copa que 'Cleopatra'; la mayor eficiencia productiva la obtuvo S×J seguido por citrumelo 'Swingle', S×E (sin diferencias estadísticas) superando ampliamente a 'Cleopatra' y 'Carrizo'. El patrón citrumelo 'Swingle' produjo 2.438 kg de fruta en 11 cosechas superando a los patrones S×E con 1.776 a 'Volkameriana' con 1.572, a S×J con 1.498 kg de fruta, respectivamente. Citrumelo 'Swingle' superó a Cleopatra en más de 1 t por árbol en la producción acumulada. Todos los patrones presentaron buena calidad de fruta para el mercado interno.

Palabras clave: citricultura, crecimiento, producción, calidad de fruta, genotipo.

Introduction

Tangerines were originated in northeast India and southeast China (Saunt, 1990), they are mainly grown in subtropical zones between latitude 40° north and south; it is the most adaptable of the cultivated citrus species. According to statistical data of FAO (2012) the main tangerine

producing countries for 2009-2010 were China, Spain, Brazil and Japan. Production of tangerine in Colombia is between 200-300 thousand tons per year, occupying second place in production before orange. 'Arrayana' tangerine is a variety preferred by Colombian growers being the most cultivated, and the only variety cultivated in Orinoquia piedmont, being one of the species described by molecular

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and morphological analysis of the genotype cultivated in Orinoquia piedmont (Ordúz-Rodríguez *et al.*, 2012). The most used rootstock for 'Arrayana' in Orinoquia piedmont is 'Cleopatra' tangerine (*Citrus reshni* hort. ex Tanaka), which is tolerant to *Phytophthora*, and to systemic diseases like CTV, Psoriasis and Xiloporosis (Castle, 1987). One of the limitations of the rootstock is the late entrance in production (Ordúz-Rodríguez *et al.*, 2006), and also the yield decrease, produced by extraordinary rains occurring in the middle of the dry season (December to March), which causes early flowering, favoring flower and fruitlets abortion caused by a water deficiency that precedes the extemporary rain.

With the propose of identify rootstocks for 'Arrayana' tangerine (*Citrus reticulata* Blanco) that allow an earlier entrance to production and the improvement of the crop's reliability by the obtaining of greater yields than the ones provided by the local rootstock, an experiment was carried out in Corpoica 'La Libertad' research center in Villavicencio (Meta). Five rootstocks used in the Colombian citriculture were evaluated and compared with 'Cleopatra', which is the main commercial rootstock of the region. In 2006 the first report of this experiment was published in which the precocity of the rootstocks and the results of five accumulated harvests were shown (Ordúz-Rodríguez *et al.*, 2006). The objective of the present work was to evaluate a wide period of the 'Arrayana' tangerine performance grafted on six rootstocks, showing the information of production of six harvests as grown up trees and also showing the morphological modification of trees during the evaluation period, productive efficiency, and fruit quality reached by each rootstock. The cumulated information of 10 harvests allows the recommendation of new rootstocks that improve the performance of the trees grafted with 'Arrayana' tangerine in the climatic and soil conditions of 'Llanos' piedmont and allows the offering of technological alternatives to local citrus growers in the interest of enhancing their economic reliability of investments.

Material and methods

Trees were planted in July of 1997 in Corpoica 'La Libertad' research center (4°03' N and 73°29'W) at 336 m a.s.l. The rootstocks evaluated were: 'Volkamerian' lemon (*Citrus volkameriana* Ten. and Pasq.); citrumelo 'Swingle' CPB 4475 (*Citrus paradisi* Macf. × *Poncirus trifoliata* (L.) Raf.), 'Carrizo' citrange (*Citrus sinensis* Osb. × *Poncirus trifoliata* (L.) Raf.); Sunki × English (SxE) (*Citrus sunki* hort. ex Tan. × *Poncirus trifoliata* (L.) Raf.); Sunki × Jacobson (SxJ) (*Citrus sunki* hort. ex Tan. × *Poncirus trifoliata* (L.) Raf.),

and commercial rootstock 'Cleopatra' tangerine (*Citrus reshni* hort. ex Tanaka). Rootstock was selected for its relevance and good performance in tropical conditions. The experimental design used was randomized blocks, with four trees per experimental unit, and three replications. Planting distance was 8×5 m.

Orinoquia piedmont climate classification corresponds to tropical wet forest (bh-t) (IGAC 2004); average annual temperature of 26°C and annual average rainfall of 2,900 mm, with moist excess for 9 months (March to November) and water deficit between December and February.

The type of soil is classified as Haplustox, with clay loam texture; this known as IV class (high terraces) and are recommended for citrus cultivation in the region (Ordúz and Baquero, 2003). Initially, the soil's bases concentration was 26% (Ca, Mg y K). Citrus orchard management was made according to Ordúz and Baquero (2003).

Vegetative and yield measurements

The morphological variables evaluated were the plant height and the canopy diameter north and south, the measures were taken during the dry season (December to February) at the end of the growth season. To determine yield, all harvest was count and sized per year (November to January). Tree height was taken from the soil to the top of the tree. Canopy volume was determined by Turrell's (1946) equation:

$$V = 0.5236 \cdot H \cdot D^2 \quad (1)$$

Where V: volume, H: height and D: diameter.

Ratio between canopy volume and annual yield expresses the canopy efficiency index as kilograms of fruit produced by cubic meter of tree canopy.

Fruit quality

Ten fruits per experimental unit were collected to realize fruit quality analyses. Fresh fruit was weighted and an electric squeezer was used for juice extraction. Juice content was determined with a graduated pipette; total soluble solids were determined with a hand refractometer and total titratable acidity was determined by its acid citric equivalent, titration with NaOH 0.1 N.

Data analysis

Variables were analyzed using the SAS 9.0 statistical software with procedure ANOVA, for means differences was realized a multiple range test with statistical Tukey at 5%.

Results and discussion

Fruit production

The highest cumulative yields of six annual harvests (2005-2011, data 2009 not shown) (Tab. 1), was obtained by 'Swingle' citrumelo, with 1,695.4 kg of fruit per tree and the rootstock Sunki × English, with 1,360.2 kg of fruit/tree. 'Swingle' citrumelo had a greater production (680 kg) than 'Cleopatra' tangerine in the evaluation of six harvests, Swingle citrumelo was over Cleopatra with 400 kg more than 'Cleopatra' as seen in 2010 harvest (Tab. 1); Sunki × English was a medium productive rootstock with a mean fruit yield of 226,7 kg/tree (Fig. 1), its best production was 347,2 kg/tree (Tab. 1). The total yield obtained by 'Arrayana' tangerine grafted onto 'Swingle' citrumelo, confirmed the previously reported outstanding performance of this rootstock (Ordúz-Rodríguez *et al.*, 2006) in the same orchard. In contrast, trials realized with 'Valencia' sweet orange showed that 'Carrizo' had better yield than 'Swingle' citrumelo in an 8 year old plantation, in the same experiment the next harvest showed no difference between them, explained by the increase of HLB infection incidence (Albrecht *et al.*, 2012).

The third place in cumulate yield was obtained by Sunki × Jacobson, with 1,092.8 kg/tree in six harvests without statistical differences with S×E. 'Arrayana' tangerine shows a medium yield when grafted onto 'Volkamerian' lemon and 'Cleopatra' tangerine; this rootstock yielded close to 1,000 kg/tree for six evaluated harvests; in this group was S×J. The lowest cumulative yield of six harvests was obtained by 'Carrizo' citrange, with 385 kg/tree.

The cumulative yield for 11 harvests of 'Arrayana' tangerine trees grafted onto six rootstocks is shown in table 2. The information related to the first five harvests was reported by Ordúz-Rodríguez *et al.* (2006) The best yield was obtained by the trees grafted onto 'Swingle' citrumelo with 2,438

kg/tree followed by S×E with 1,776 kg/tree, 'Volkamerian' (1,572 kg/tree), and S×J (1,498 kg/tree). 'Swingle' citrumelo overpassed the local rootstock 'Cleopatra' by 1,050 kg/tree, the rootstock with the lowest cumulate production for 11 years was 'Carrizo' citrange. In trials realized with 'Pera Olympia' sweet orange the cumulative yield for harvests of 8 years showed that 'Volkamerian' lemon was higher than 'Cleopatra' (Castle and Baldwin, 2011).

TABLE 2. Cumulative yield of 11 harvests of 'Arrayana' tangerine grafted onto six rootstocks. The first phase is composed by five harvests made by Ordúz-Rodríguez *et al.* (2006), second phase corresponds to fully developed trees (2005-2011, no data for 2009).

Rootstock	Period cumulative yield (kg/tree)		
	1 st	2 nd	Total
Volkameriana	554.52	1,018.47	1,572.99
Citrumelo 'Swingle'	742.79	1,095.36	2438.15
Cleopatra	378.31	1,055.67	1,433.98
Carrizo	134.10	438.68	572.78
Sunki × English	416.39	1,360.2	1,776.59
Sunki × Jacobson	340.14	1,158.81	1,498.95

In the conditions of Orinoquia piedmont, tangerines blooms once per year (Ordúz, *et al.*, 2010) inducted by water stress in periods of low rainfall (Davies, 1997); 'Cleopatra' is sensitive to climatic conditions of water deficit occasioned by unseasonable rainfalls that occurred in dry seasons during the flowering-curdled phase (Mateus *et al.*, 2010), 'Cleopatra' was also reported as a rootstock of late entrance in production (Castle, 1987). Bassal (2009) confirmed this characteristic in 'Marisol' clementine (*Citrus reticulata* Blanco.), where 'Cleopatra' obtained the lowest yield versus 'Carrizo' and 'Swingle' citrumelo after 5 years of planted. Otherwise 'Carrizo' did not show an improvement in yield with the pass of time, In 'Tahiti' lime Cantuarias-Avilés *et al.* (2012) found that plants grafted on 'Carrizo' produced better cumulative yield values (7 years) than citrumelo.

TABLE 1. Tree annual yield of 'Arrayana' tangerine grafted onto six different rootstocks. 2005-2011. R.C 'La Libertad'.

Rootstock	Production per tree (kg)						Cumulative
	2005	2006	2007	2008	2010	2011	
Volkamerian	105.18 ab	203.03 a	229.92 a	162.77 dc	119.29 c	198.28 b	1,011.8 c
Citrumelo 'Swingle'	142.28 a	234.17 a	275.05 a	325.32 ab	403.93 ab	314.61a	1,695.4 a
Cleopatra	64.07 bc	77.66 a	183.65 a	250.08 bc	285.26 b	194.95 b	1,016.7 c
Carrizo	21.63 bc	93.59 ab	24.13 b	179.18 dc	100.15 c	20.00 b	385.00 d
Sunki × English	128.77 a	214.81 a	222.32 a	347.3 a	305.82 ab	141.18 b	1,360.2 ab
Sunki × Jacobson	119.29 a	239.80 a	183.77 a	155.78 d	234.43 b	225.74 ab	1,092.8 bc

Means followed by different letters indicate significant difference according to Tukey's test ($P \leq 0.05$).

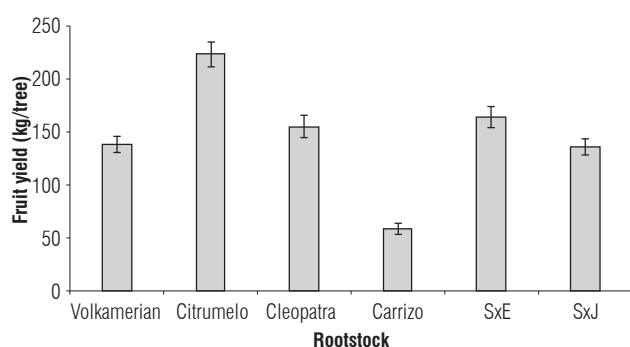


FIGURE 1. Average annual production of 'Arrayana' tangerine grafted onto six different rootstocks, 2000-2011 (excluding the 2009 harvest). Error bars represent the standard deviation.

Figure 1 shows the mean yield of 'Arrayana' grafted onto six rootstocks. The rootstock that produced the highest annual yield was 'Swingle' citrumelo with 282.6 kg/tree, being better than 'Cleopatra' by 113 kg/tree mean annual yield and SxE 56 kg/tree, which was the second rootstock in cumulate annual yield.

Vegetative growth

In 2005, plant height was similar to the first phase evaluated by Orduz-Rodríguez *et al.* (2006); 'Cleopatra' showed the maximum height of all the rootstocks during the second phase with statistical differences in 2011, except with 'Carrizo'.

Canopy volume

'Cleopatra' had the biggest evaluated canopy volume in the second phase, but it was not significantly different from 'Swingle' citrumelo in 2006 and 2008-2011. SxJ, 'Carrizo' and 'Volkamerian' were grouped as lower volume canopies, among them SxJ was the canopy with lowest volume in the 2009-2011 period (Tab. 4).

Statistically significant differences were found between the first phase (Orduz-Rodríguez *et al.*, 2006) and the second, where 'Carrizo' was the only one with lowest canopy volume with statistical differences. Georgiou (2002) obtained similar results with the canopy volume of 'Clementine' tangerine (*Citrus reticulata* Blanco) grafted onto 'Carrizo' and 'Swingle' citrumelo. Cantuarias-Avilés *et al.* (2010) in 'Okatsu' satsuma (*Citrus unshiu* Marow) trees grafted onto 'Carrizo' obtained greater canopy volume than onto 'Swingle' citrumelo; this corroborates the influence of tropical conditions on the vegetative growth when compared to subtropical zones. With 'Nova' tangerine, Georgiou (2000) found that plants grafted onto 'Volkamerian' rootstocks produced bigger canopy volumes than onto 'Swingle' citrumelo.

Production efficiency

The second phase did not show an ascendant pattern in productive efficiency, as was seen in the first phase, where

TABLE 3. Tree height of 'Arrayana' tangerine grafted onto six rootstocks, during 2005-2011.

Rootstock	Tree height (cm)						
	2005	2006	2007	2008	2009	2010	2011
Volkamerian	413.33 b	447.9 b	478.75ab	455.8 d	435.8 d	455.58ab	463.33 c
Citrumelo 'Swingle'	434.58ab	462.5ab	501.67ab	490.8abc	461.7abc	446.33 b	485.83 c
Cleopatra	458.75 a	482.1 a	525.00 a	515.4 ab	493.3 ab	530.42 a	535.00 a
Carrizo	408.33b	435.4 b	478.33ab	519.2 a	500.00 a	491.83ab	534.17ab
Sunki × English	432.5 ab	460.8ab	490.00ab	475.40bcd	445.00bcd	490.67ab	490.00bc
Sunki × Jacobson	409.86b	441.40b	428.42b	442.2 cd	404.50cd	434.58 b	445.83 c

Means followed by different letters indicate significant difference according to Tukey's test ($P \leq 0.05$).

TABLE 4. Canopy volume of 'Arrayana' tangerine grafted onto six different rootstocks, since 2005-2011.

Rootstock	Canopy volume (m ³ /tree)						
	2005	2006	2007	2008	2009	2010	2011
Volkamerian	34.51 b	48.58ab	52.53 ab	60.95 bc	59.66 bc	64.24 bc	73.66bc
Citrumelo 'Swingle'	40.12 b	53.43 a	47.79 b	73.99 ab	73.94 ab	81.40 ab	90.31ab
Cleopatra	47.61 a	59.45 a	69.15 a	83.13 a	84.18 a	102.35 a	110.38a
Carrizo	24.19 c	36.38 b	39.17 b	50.38 c	58.79 bc	60.69 bc	59.75 c
Sunki × English	36.64 b	49.46ab	52.48 ab	67.14abc	63.64abc	66.71 bc	83.68 b
Sunki × Jacobson	33.19 b	46.41ab	50.24 b	52.50 bc	49.78 c	52.96 c	58.83 c

Means followed by different letters indicate significant difference according to Tukey's test ($P \leq 0.05$).

the efficiency increased according to tree growing (Ordúz-Rodríguez *et al.*, 2006). The rootstocks showed a similar pattern than first phase, except for ‘Cleopatra’ that showed a low productive efficiency, this rootstock only had similar statistical conditions with other rootstocks in 2008 and 2010. In average, the rootstocks that obtained the lowest productive efficiency were ‘Cleopatra’ and ‘Carrizo’ (Tab. 5), following the same performance seen in the first phase (Ordúz-Rodríguez *et al.*, 2006).

SxJ was the rootstock that obtained the maximum productive efficiency in years average (Tab. 5) was 156% superior to ‘Cleopatra’, followed by ‘Swingle’ citrumelo.

Mourão Filho *et al.* (2007) with ‘Fallglo’ tangerine (*Citrus reticulata* Blanco), found similar performance between ‘Cleopatra’ and ‘Swingle’ citrumelo, being the last one the best in productive efficiency; in the same experiment, with ‘Sunburst’ tangerine (*Citrus reticulata* Blanco), ‘Cleopatra’ overpassed ‘Swingle’ citrumelo without statistical differences.

The rootstocks with the highest productive efficiencies obtained, allow plantation of higher plant densities and the obtaining of a better yield/ha, this was the case of SxJ that also had the lowest canopy volumes (58.8 m³) in 2011 showed the best productive efficiency per year with 5.1 kg m⁻³ overpassing ‘Cleopatra’ with more than 100 m³ of

canopy that can only produce 1.99 kg m⁻³ per year. Trees grafted onto rootstocks that generate canopies with lower volumes and high productive efficiencies, as was the case of SxJ and ‘Swingle’ citrumelo, allow plantations with better densities and increased production per area and reliability of soil use.

Fruit quality

‘Carrizo’ obtained the highest fresh fruit weight and SxJ the lowest, without statistical differences with other rootstocks (Tab. 6) this table shows how the fruit in 2006 overpassed the optimal fruit size, reaching weights of around 200 g.

Georgiou (2000) reported for ‘Nova’ tangerine that ‘Volkamerian’ rootstock produced bigger fruits than ‘Swingle’ citrumelo and ‘Carrizo’. Cantuarias-Avilés *et al.* (2010) as well as in other important regions in the world, is based on very few mandarin cultivars. This fact leads to a short harvest period and higher prices for off-season fruit. Cantuarias-Avilés *et al.* (2010) report that ‘Carrizo’ was the rootstock that produced the biggest fruits of ‘Okitsu’ tangerine but without statistical differences to ‘Swingle’ citrumelo. In trials involving ‘Valencia’ sweet orange Bowman *et al.* (2016) observed that ‘Cleopatra’ produced the fruits with heaviest weight, followed by ‘Swingle’ citrumelo.

TABLE 5. Productive efficiency of ‘Arrayana’ tangerine grafted onto six rootstocks, 2005-2011 period.

Rootstock	Canopy productive efficiency (kg m ⁻³)						Average
	2005	2006	2007	2008	2010	2011	
Volkamerian	3.17 a	4.49 ab	4.47 ab	2.78 b	1.85 b	2.7 ab	3.26 ab
Citrumelo ‘Swingle’	3.28 a	5.01 ab	5.71 a	4.73 ab	5.53 ab	4.44 a	4.77 a
Cleopatra	1.37 b	1.51 b	2.33 b	2.83 ab	2.47 ab	1.61 b	1.99 b
Carrizo	1.11 b	3.24 ab	2.10 b	4.17 ab	1.80 b	1.97 ab	2.2 b
Sunki × English	3.86 a	4.31 ab	4.55 ab	5.52 a	5.77 ab	1.89 b	4.31 ab
Sunki × Jacobson	3.73 a	8.52 a	3.75 ab	3.57 ab	6.53 a	3.83 ab	5.1 a

Means followed by different letters indicate significant difference according to Tukey’s test ($P \leq 0.05$).

TABLE 6. Fruit quality of ‘Arrayana’ tangerine grafted onto six different rootstocks, year 2006.

Rootstock	Fresh weight (g)	Juice content (%)	ATT (%)	SST (%)	Ratio SST/ATT
Carrizo	240.73 a	34.11 a	0.51 a	8.68 b	17.14 a
Citrumelo ‘Swingle’	200.72 a	36.79 a	0.56 a	8.78 ab	15.87 ab
Cleopatra	220.21 a	33.53 a	0.56 a	8.77 ab	15.81 ab
SxJ	202.87 a	33.89 a	0.53 a	8.16 b	16.48 ab
SxJ	194.97 a	36.85 a	0.55 a	9.08 a	16.61 a
Volkameriana	216.91 a	36.94 a	0.55 a	8.12 c	14.80 b

Means followed by different letters indicate significant difference according to Tukey’s test ($P \leq 0.05$).

The juice content showed no differences between the rootstocks, 'Volkamerian' was the rootstock that produced the best percentage of fruit (36.94%) and the lowest was 'Cleopatra' (33.53%). The rootstocks did not influence the total titratable acidity (TTA). On the other hand, the highest total soluble solids (TSS) content was obtained by S×J followed by S×E, and the lowest value was observed in 'Volkamerian'.

The fruit quality was similar to the first phase of evaluation in regard to the TSS/TTA ratio, 'Carrizo' was the one with the highest values without statistical differences with the other rootstocks, except for 'Volkamerian' that was the lowest one. The results were similar to the ones described by Chaparro-Zambrano *et al.* (2015), obtained with the same rootstocks where 'Valencia' sweet orange were grafted and grown under tropical conditions. All rootstocks values were between normal ranges to consider all of them as good rootstock for fruit quality parameter.

Conclusions

The response in parameters of yield, high, canopy volume, productive efficiency and fruit quality allow the identification of 'Swingle' citrumelo and S×E as rootstocks with aptitude for new plantations of 'Arrayana' tangerine in the region, overpassing the commercial rootstock 'Cleopatra' in the main productive index, producing trees of lowest high and best productive efficiency.

The S×J, S×E and 'Swingle' citrumelo showed the lowest canopy volume and the best productive efficiency in 'Arrayana' tangerine, because of this qualities, it allows increasing the plant density to 300-350 trees/ha, with the possibility of increasing yield by this way.

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