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Performance of Minneola tangelo trees grafted over six rootstocks in Colombia Tropical Lowland (1997-2010)

Comportamiento de tangelo 'Minneola' injertado sobre seis patrones en el trópico bajo de Colombia (1997-2010)

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Abstract

'Cleopatra' tangerine (*Citrus reshni* hort. ex Tanaka) is a commonly used rootstock in the piedmont of Meta department, Colombia for establishing of commercial citrus orchards. Have allowed a late production entrance rootstock and produced big plants when grafted with tangelo 'Minneola' (*C. reticulata Blanco x C. paradise* Macf), decreasing the productive efficiency in plants and hard crop practices. The evaluated performance were as follows: tree size, productive efficiency and fruit quality of tangelo 'Minneola' grafted in six rootstocks. It found that the cumulated production of 11 years was better with Citrumelo 'Swingle' (*Citrus paradisi* Macf. × *Poncirus trifoliata* (L.) Raf) with 1388.3 kg tree^{-1}, followed by 'Cleopatra' (*Citrus reshni* hort. ex Tanaka) with 893.2 kg.tree^{-1}, in last place was 'Carrizo' (*Citrus sinensis* Osb. × *Poncirustrifoliata* (L.) Raf) with 182.9 kg tree^{-1}. The other rootstocks, had a medium production. The greatest height and canopy value, was found with 'Cleopatra' without significant differences with Citrumelo 'Swingle'. In fruit quality no significant differences occurred.

Keywords: Citrus, ecophysiology, genotype, Piedmont of Meta-Colombia.

Resumen

Mandarina 'Cleopatra' (*Citrus reshni* hort. ex Tanaka) ha sido el patrón más utilizado en el piedemonte del Meta (Colombia) para el establecimiento de cultivos comerciales de cítricos. Ha sido reportado de tardía entrada en producción y de baja eficiencia productiva por inducir arboles de gran tamaño. Este patrón es usado con tangelo 'Minneola' (*Citrus reticulata* Blanco *x Citrusparadisi* Macf), hibrido de importancia económica en el piedemonte del Meta, con deficientes resultados comerciales. Por esta razón se evaluó el comportamiento (tamaño de árboles, eficiencia productiva y calidad de fruta) de tangelo 'Minneola' injertado sobre seis patrones incluyendo a 'Cleopatra' como testigo regional. Se encontró que la producción acumulada de 11 cosechas anuales fue mayor con Citrumelo 'Swingle' (*Citrus paradisi* Macf. × *Poncirus trifoliata* (L.) Raf) seguido por 'Cleopatra' (*Citrus reshni* hort. ex Tanaka) con 1388.3 kg árbol^{-1} y 893.2 kg árbol^{-1}, respectivamente, mientras que el rendimiento más bajo se obtuvo con el patrón 'Carrizo' (*Citrus sinensis* Osb. × *Poncirus trifoliata* (L.) Raf) con182.9 kg árbol^{-1}. Los demás patrones presentaron una producción intermedia. La mayor altura y tamaño de copa se encontró con 'Cleopatra' sin diferencias estadísticas significativas con Citrumelo 'Swingle'. No se presentaron diferencias significativas sobresalientes entre patrones con respecto a calidad de fruto.

Palabras clave: Cítricos, ecofisiología, genotipos, piedemonte del Meta, Colombia.

Introduction

The selection of plant material (rootstock and scion) is one of the most important decisions for the establishing of a citrus crop. The permanent nature of orchards and the influence of the rootstock on the scion, especially by the modifications. In the supply of water and nutrients through the roots (Syvertsen & Albrigo, 1980). The interaction between the rootstocks and cultivars were used as scion should be studied at a local level in order to respond to edaphoclimatic conditions of the study area, which will enhance the recommendations for the growers interested in this crop.

In Colombia, tangelo cv. 'Minneola' and cv. 'Orlando' are the more common cultivated varieties (Orduz & Mateus, 2012), these coming from a the crossing of 'Dancy' tangerine (*Citrus reticulate* Blanco) and 'Duncan' grapefruit (*Citrus paradise* Macfad) effectuated by Webber and Swingle (Davies & Albrigo, 1994). Between these two tangelo cultivars, 'Minneola' is the most common in Colombia. Particularly, in Meta department tangelo fruit is the highest value citrus in domestic market. 'Minneola' tangelo crops is cultivated in 'Meta' are less susceptible to 'alternaria' disease and its production range between 15 and 40 tons/year in 'Lejanias' municipality (Orduz *et al.*, 2007). Davies & Albrigo (1994), describe 'Cleopatra' tangerine as rootstock with medium tolerance to *Phytophthora* sp., and viral diseases as Citrus Tristeza Virus (CTV), exocortis and psoriasis (Castle, 1987). Opposite to this Orduz-rodríguez *et al.* (2011), asseverate that in edaphoclimatic conditions presents in Meta's piedmont would limit the 'Cleopatra' productive potential, different orange and citrus hybrids (including tangelo) because it induces a late production entrance and the diminishing of fruit size when the trees reach a productive age. Also, has been reported that induce a big size of canopy in tropical conditions (Cunha *et al.*, 2013), this difficult cultural labors, reduce productive efficiency in orchard, and investment profitability.

In order to offer technological assistance oriented to improve competitiveness of citrus fruits growers of Meta piedmont-Colombia, an experiment was established. The aim of this research was to evaluate the vegetative response, yield, productive efficiency and fruit quality of 'Minneola' tangelo grafted over six rootstock used in Colombian citrus crops.

Materials and methods

The orchard was located in the research center 'La Libertad' (4° 03'N - 73°29' W) with an altitude of 336 m.a.s.l. The experiment was established in a soil of high plains, classified as Typic Haplustox, and clay-loam texture recommended for citrus crops in the region. Experimental area is located in tropical rain forest climate zone, according to Holdridge classification (IGAC, 2014) . It has monomodal rainfall regimen, average rainfall of 2955 mm, average temperature of 26°C and 80% of relative humidity.

Trees were planted in the second semester of 1997; plant distance was 8m between rows and 5m between plants. Experimental unit was make up by four trees. The experimental design was a completely block randomized, including six treatments according to the number of rootstocks (Table 1) and three replicates. Weed control, fertilization and agronomic manage were made according to recommendations from Orduz & Baquero (2003), for soils of high plains of Meta piedmont.

Table 1. Evaluated rootstocks

Common name	Scientific name
Volkamerian	*Citrus volkameriana* Ten. y Pasq
Citrumelo Swingle-CPB 4475-	*Citrus paradisi* Macf. × *Poncirus trifoliata* (L.) Raf
Citrange Carrizo	*Citrus sinensis* Osb. × *Poncirus trifoliata* (L.) Raf
Sunki**× E**nglish (S x E)	*Citrus sunki* Hort. ex Tan. × *Poncirus trifoliata* (L.) Raf
Sunki**× J**acobson (S x J)	*Citrus sunki* Hort. ex Tan. × *Poncirus trifoliata* (L.) Raf
Cleopatra tangerine	*Citrus reshni* Hort. ex Tanaka

Experimental rootstocks plants were propagated in a greenhouse using seeds provided by mother trees of Corpoica 'Palmira', Valle-Colombia. In turn, local crops provided a commercial scion. Yearly tree production, vegetative growth and fruit quality were documented.

Vegetative growth was yearly sized during dry season, between December and February since 1998 to 2010. The north-south and east-west Canopy diameter and tree height were registered. Upon these values canopy volume was estimated using the Turrell (1946) formula (Equation 1).

$$V = 0.5236 \cdot H \cdot D^2 \qquad \text{Equation 1}$$

Where:

H= height of canopy

D= diameter.

Productive efficiency was obtained with the relation between canopy volume and annual production, this was expressed in kg of fruit produced by cubic meter of canopy ($kg.m^{-3}$).

To determine productive performance, trees were harvested individually and sum the production of the year from the period 2000 to 2010. The total sum of this, is the cumulative production per rootstocks. At the end of each harvest, a sample of 10 fruits per experimental unit were taken for quality fruit analysis. It included weight, longitudinal and transversal diameter and juice percent. Juice volume was determined through a calibrated test tube, total soluble solids (TSS), were calculated using a handy refractometer, and total titratable acid was determined by NaOH 0.1 N titration.

For ANOVA proceeding, to determine the effects of 'Minneola' tangelo, the data were processed and analyzed using SAS software 2003 ® and for mean separation, was used multiple range test with Tukey statistical error at 5%.

Results and discussion

Production

The rootstocks with the better accumulated productions in the evaluated period were as follows: 'Citrume' with 1388.3 kg $tree^{-1}$ and 'Cleopatra' with 893.2 kg $tree^{-1}$ (Table 2). 'Carrizo', obtained the lowest production in every year evaluated also the rootstock with the lowest cumulated production with 182.9 kg m^{-1}. According to Table 2, Cleopatra was confirmed as a rootstock that induces a late entrance to production in 'Minneola' tangelo.

Sunki x English (SxE) and Sunki x Jacobson (SxJ) were middle rootstocks regarding cumulated production with 811.8 and 794 kg $tree^{-1}$, respectively. These had a lower performance than 'Cleopatra'. However, they showed a constant productive according to Table 2 results. In addition, 'Volkamerian' had a cumulated production of 661.1 kg $tree^{-1}$, behind SxE and SxJ outcomes.

Table 2. Yearly and total production per tree of 'Minneola' tangelo grafted over six rootstocks

	Production (kg $tree^{-1}$)											
Rootstock/year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Volkamerian	5.3 a	4.9 a	15.4 a	38.4 ab	122.7 a	111.5 bc	50.5bc	31.5 bc	108.7 b	86.5 ab	85.8bc	661.1
Citrumelo	3.5 a	12.4 a	30.4 a	11.5 ab	153.5 a	228.8 a	117.7 a	106.5 a	383.4 a	176.0 a	164.7 a	1388.3
Cleopatra	1.1 a	3.2 a	16.8 a	40.0 a	106.7 a	86.7bc	67.4 abc	87.7 ab	257.8 ab	154.4 a	71.3bc	893.2
Carrizo	3.9 a	7.8 a	0.3 a	1.0 b	22.4 b	39.1 c	17.3 c	10.8 c	10.8 c	20.6 ab	48.9 c	182.9
S x E	12.7 a	8.4 a	2.8 a	30.9 ab	130.9 a	150.6 abc	57.1 abc	87.9 ab	87.9 ab	138.0 a	104.7abc	811.8
S x J	1.2 a	8.0 a	4.6 a	35.6 ab	115.5 a	172.3 ab	85.3 ab	74.9 ab	74.9 ab	93.9 ab	127.9 ab	794.0

Values with different letter in each column indicates significant differences (P<0.05)

Vegetative growth

Accumulated data in 12 years of records showed that 'Cleopatra' obtained the higher trees in average (Table 3), reaching the max height of 7.1m in 2010. This without statistical differences contrasting to 'Swingle' citrumelo. The others rootstocks were in a similar range of height.

Table 3. Tree height of 'Minneola' tangelo grafted over six rootstocks

	Tree height (m)											
Rootstock/year	1998	1999	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010
Volkamerian	1,8 a	3,0 a	3,5 a	4,5 a	4,9 ab	5,2 a	5,6 ab	5,7 ab	5,9 ab	5,8 bc	6,2 b	6,1 b
Citrumelo	1,4 bc	2,5 bc	3,3 ab	4,4 a	4,7 ab	5,2 a	5,4 ab	5,6 ab	5,8 ab	6,0 b	6,2 b	6,5 ab
Cleopatra	1,7 ab	2,9 ab	3,5 a	4,5 a	5,1 a	5,4 a	5,9 a	6,2 a	6,4 a	6,7 a	6,9 a	7,1 a
Carrizo	1,3 c	2,4 c	2,7 c	3,5 b	3,8 c	4,4 b	4,6 c	4,8 c	5,0 c	5,3bc	5,5 bc	5,8 b
S x E	1,2 c	2,3 c	2,9 bc	4,0 ab	4,5 ab	5,1 a	5,1 bc	5,5 ab	5,8 b	6,0 b	6,2 b	6,4 b
S x J	1,1 c	2,3 c	2,9 bc	3,9 ab	4,7 ab	4,9 ab	5,0 bc	5,3 bc	5,5 bc	5,7 bc	5,8 bc	6,1 b

Values with different letter in each column indicates significant differences (P<0.05)

In the last evaluation year, 'Cleopatra' was the rootstock that induces the biggest canopy volume in 'Minneola' tangelo reaching 212.9 m^3, followed by 'Citrumelo' and 'Volkamerian' in the same statistic group with values of 181.1 and 180.6 m^3 each one. In descendent order, the SxE and SxJ varieties showed intermediate values. The rootstock with lowest values was 'Carrizo' with 111.8 m^3 (Table 4).

Table 4. Canopy volume (m^3) of 'Minneola' in tangelo grafted over six rootstocks

	Canopy volume (m^3)											
Rootstock/year	1998	1999	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010
Volkamerian	2.5 a	11.4 a	22.6 a	52.9 a	72.0 a	102.3 a	134.7 a	121.7 a	155.7 a	148.9 ab	167.4 ab	180.6 ab
Citrumelo	1.2 bc	8.0abc	18.3 ab	50.5 ab	76.6 a	113.5 a	137.1 a	148.9 a	166.8 a	159.6 ab	186.7 a	181.1 ab
Cleopatra	1.6 ab	8.1 ab	17.1 abc	45.3 abc	71.6 a	105.5 a	137.7 a	143.1 ab	160.9 a	181.5 a	199.3 a	212.9 a
Carrizo	0.5 c	3.4 c	5.6 d	12.0 d	20.2 b	38.9 b	52.1 b	58.1 c	70.9 b	70.7 c	80.9 c	111.8 b
S x E	1.0 bc	5.6 bc	12.8 bcd	33.1bc	58.2 a	92.2 a	118.8 a	129.3 ab	151.3 a	148.7 ab	156.0 ab	159.0 ab
S X J	0.5 c	4.0 bc	9.3cd	29.4 dc	59.7 a	84.6 a	99.0 a	105.7 b	127.8 a	129.2 b	117.0 bc	129.1 b

Values with different letter in each column indicates significant differences (P<0.05)

In Table 5, the data indicates that 'Swingle' citrumelo was the best productive efficiency with 1.15 kg m^{-3}. It was better than 'Cleopatra' register of 0.74 kg m^{-3}. SxE and SxJ, also showed superior productive efficiency over 'Cleopatra's' performance. Although, they had a lower cumulate production, they could reach a better yield per area because the lower size of trees. 'Volkamerian' rootstock showed a middle productive efficiency with 0.75 kg m^{-3}, otherwise 'Carrizo' was the rootstock with lowest values.

Table 5. Productive efficiency of 'Minneola' tangelo grafted over six rootstocks

	Productive efficiency (kg m^{-3})								
Rootstock/year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total average**
Volkamerian	0,72 a	2,04 a	0,93 bc	0,37 a	0,2 b	0,76 b	0,54 ab	0,47 a	0,75
Citrumelo	0,13 bc	1,41 a	1,81 a	0,96 a	0,68 a	2,43 a	0,91 a	0,83 a	1,15
Cleopatra	0,58 ab	1,05 a	0,62 c	0,51 a	0,55 a	1,5 ab	0,77 a	0,33 b	0,74
Carrizo	0,02 c	0,57 a	0,75 c	0,31 a	0,17 b	1,28 ab	0,16 b	0,28 b	0,44
S x E	0,48 abc	1,19 a	1,18 c	0,43 a	0,61 a	2,41 a	0,91 a	0,74 a	0,99
S x J	0,54 ab	0,96 a	1,6 ab	0,84 a	0,56 ab	1,77 ab	0,7 a	0,93 a	0,99

Values with different letter in each column indicates significant differences (P<0.05)

Fruit quality

Concerning the fruit weight were not reported differences between fresh fruit in the evaluated rootstocks. The biggest mean fruit weight was obtained by 'Swingle' citrumelo with a difference of 25 g respect of SxJ and 'Volkamerian'. SxE showed and intermedium fruit weight (360.8 g) between the other five rootstocks, otherwise 'Cleopatra' and 'Carrizo' induce a low fruit weight with 338.0 g and 305.7, respectively (Table 6).

There was not significant difference for juice content among rootstocks. However, SxE obtained the best juice content (47.5 %), in contrast 'Carrizo' juicer percentage was 39.41%, being the rootstock with lowest juice content. 'Swingle' citrumelo obtained the best fresh fruit weight, without having the best juice percentage. In the parameter of TSS the 'Carrizo', 'Swingle' 'Cleopatra' and SxJ were the rootstocks with highest values without statistical differences among them, followed by SxE and 'Volkamerian', these were the lowest values.

'Carrizo' was the rootstock that produce the 'Minneola' fruits with highest TTA (0.9) showing statistical differences in respect to the others rootstocks, except SxJ. These characteristics has led to the fruit produced by 'Carrizo' reach later the commercial maturity. The TTA values of 9 month fruits oscillated between 0.6 and 0.7. For citrus fruit ratio TSS/TTA values over 9, guarantee and optimum fruit maturity. Respect that, all rootstocks were over 9 value, however 'Carrizo' produced the fruit with lowest

value (10.6). The other rootstocks range of 12.4 to 15.4, being 'Swingle' the rootstock with the highest value. 'Swingle' must be evaluated to determine an early harvest for trees grafted over this rootstock.

Table 6. Fruit quality of 'Minneola' tangelo grafted over six rootstocks

Rootstock	F.W (g)		Juice (%)		TTA (%)		TSS (%)		TSS/TTA	
Volkamerian	375.9	a	46.6	a	0.61	b	7.83	c	13.4	ab
Swingle Citrumelo	401.0	a	43.8	a	0.60	b	8.55	ab	15.4	a
Cleopatra	338.0	a	44.0	a	0.64	b	8.45	ab	13.6	ab
Carrizo	304.7	a	39.4	a	0.90	a	8.80	a	10.6	b
S x E	360.8	a	47.5	a	0.65	b	8.09	bc	12.8	ab
S x J	376.0	a	44.7	a	0.70	ab	8.39	ab	12.4	ab

Accumulated data aims to 'Swingle' citrumelo, was the best rootstock for fruit production in Meta piedmont conditions, followed by 'Cleopatra' SxE, 'Volkamerian', SxJ and 'Carrizo'. In this sense, Levy & Lifshitz (1995), in the evaluation of 7 rootstocks found that 'Cleopatra', was superiror than 'Volkamerian' and 'Carrizo' when they were grafted under 'Minneola' tangelo; while was true that 'Swingle' was not in this evaluation. The performance of the others rootstocks were similar to the present experiment. In other commercial scion species, like 'Arrayana' (*Citrus reticulate* Blanco.) and 'Folha Murcha' sweet orange (*Citrus sinensis* Osbeck.), 'Swingle' citrumelo had showed best productive outcomes in respect to the others evaluated rootstocks (Orduz-Rodríguez *et al.*, 2006; Cantuarias-Aviles *et al.*, 2011).

In Table 2, were 2 productive pikes for the evaluated period, one in 2005 and the other in 2008. Before these years, there was a fall for two productive cycles (years) 2006-2007 for the first year and 2009-2010 for the second. This suggest a recovery time for the plants after a high production. This alternation was similar in 'Valencia' sweet orange (*Citrus sinensis* Osbeck.) established in the tropical lowlands in 'La Libertad' research center, where is mentioned that the behavior could be influenced by the recovery of plants after a high energetic inversion realized by the trees in years of peak production. It is mentioned as years "on" where the plants responds through the development of vegetative shoots and the diminishing of flowering shoots in the next years known as "off" years (Orduz-Rodríguez & Garzón, 2012; Chaparro-Zambrano *et al.*, 2015). However, in this "off" years 'Swingle' citrumelo, was the rootstock with best cumulated production per tree, signaling a good adaptation to the environmental conditions of Meta piedmont.

'Cleopatra' was characterized as a rootstock that produce big and vigorous trees, with a depth and numerous dense root system (Davies & Albrigo, 1994). Orduz-Rodríguez *et al.* (2006), found that after seven year of evaluation in 'Arrayana' tangerine grafted over six rootstocks, 'Cleopatra' was the rootstock that generate the biggest canopy volume even than 'Volkamerian', SxE, SxJ and 'Swingle', the same result as the present experiment. In the same experiment, Orduz-Rodríguez *et al.* (2006), found that 'Carrizo' was the rootstock that produced trees with less growth values due to his low adaptation to the conditions of acid soil of the Meta piedmont, result that was ratified in 'Minneola' tangelo.

Jackson & Futch (1993), identified 'Minneola' tangelo as a vigorous tree in subtropical conditions, whatever canopy development in tropical condition was even bigger, which can be related to cumulated heat unit, related to annual high temperatures. For Villavicencio located in tropical lowlands, the zone is characterized by a high annual rainfall, relative humidity, and middle temperature; plants can grow continuously during all year permitting the high accumulation of dry mass and producing trees with high foliage and canopy volume, being tangelo one of the biggest citrus cultivars in the world. As probe of this fact, was the canopy volume at 11 years of planted three commercial species in the same location at the same year in 1997, the answer of that was 'Arrayana' 73.12 m^3, 'Dancy' tangerine 69,3 m^3 and 'Valencia' sweet orange with 43.62 m^3; if these is compared to 'Minneola' tangelo with 181.47 m^3 of canopy (Chaparro-Zambrano *et al.*, 2015; Mateus-Cagua & Orduz-Rodríguez, 2015). The big size of trees produced in the experiment difficult the pruning and harvest labors, so then is recommended to evaluate rootstocks that produce medium or dwarf trees, sizes that allow plantation with high density and best or similar yields to increase the income per hectare.

With respect to fruit quality, the fresh fruit weight range between 304 and 400 g, and a juice percentage of 39 and 47%. In other experiments, Levy & Lifshitz (1995), obtained fruit smaller size with weights between 117 and 134 g and a juice percentage of 54-56% in the rootstocks 'Cleopatra', 'Volkamerian' and 'Carrizo'. Escalona *et al.* (1998), obtained in 'Orlando' tangelo fruits with the fresh weight of 180.92 g. Fallahi *et al.* (1991), in their experiment in 'Orlando' tangelo obtained the best ratio of TSS/TTA when was grafted over 'Carrizo' 13,1 and 'Volkamerian' of 13,5. However, the best rootstock in the current experiment shows a high ratio indicating that it could induce and early fruit picking, this rootstock produced lower trees and best fruit weight in tropical lowland conditions.

Conclusion

After the performed experiment is possible to conclude. Firstly, the 'Swingle' citrumelo has increased the production per tree of 'Minneola' tangelo in a 36% compared to the local commercial rootstock 'Cleopatra'. Secondly, the best productive efficiency of 'Minneola' tangelo was obtained when it was grafted in 'Swingle' citrumelo (35% superior to 'Cleopatra'), followed by SxE and SxJ. Thirdly, the rootstocks evaluated still produce big trees, so then is necessary to probe dwarfing rootstocks, in order to increase plantation density and facilitate cropping and harvesting activities. Finally, all rootstocks accomplished the commercial requirements for fruit quality.

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