



Agronomía Colombiana

ISSN: 0120-9965

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Universidad Nacional de Colombia  
Colombia

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Lowland. 2001-2013  
Agronomía Colombiana, vol. 33, núm. 1, 2015, pp. 43-48  
Universidad Nacional de Colombia  
Bogotá, Colombia

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# Performance of 'Valencia' sweet orange grafted in different rootstocks, Colombia Tropical Lowland. 2001-2013

## Comportamiento de naranja 'Valencia' injertada en diferentes patrones, en el trópico bajo de Colombia. 2001-2013

Hans Nicolas Chaparro-Zambrano<sup>1</sup>, Heberth Augusto Velázquez<sup>1</sup>, and Javier Orlando Orduz-Rodríguez<sup>1</sup>

### ABSTRACT

'Valencia' sweet orange is widely cultivated in Colombian tropical lowlands, with low yields and a lack of technology. As a result, nine rootstocks commonly used in tropical zones: 'C-35', 'Carrizo', 'Swingle' citrumelo or CPB 4475, 'Cleopatra', 'Sunki × English', 'Volkamer', 'Webberi' and 'Yuma' were evaluated. The plants were established in 2001 and were evaluated for vegetative growth, fruit yield and quality for 10 years (2004-2013). The obtained results indicated that 'Sunki × English' and 'Volkamer' were the best rootstocks for fruit yield and the worst was 'Yuma'. Furthermore, all of the rootstocks, except 'Yuma', stabilized their height in the last year. In terms of volume, 'Amblycarpa' and 'Cleopatra' were the bigger plants and 'Yuma' was the smallest. In addition, for yield efficiency, 'Yuma' had the best rootstocks, followed by 'Sunki × English'. All of the rootstocks showed a similar fruit quality, except for 'Sunki × English', which obtained the highest total soluble solids/total titratable acids ratio.

**Key words:** ecophysiology, fruit quality, genotype, propagation, *Citrus*.

### RESUMEN

La naranja 'Valencia' es ampliamente cultivada en el trópico bajo de Colombia, con bajos rendimientos y falta de tecnología. Para responder a estos requerimientos, fueron evaluados nueve patrones comúnmente usados en las zonas tropicales, 'C-35', 'Carrizo', 'Swingle' citrumelo o CPB 4475, 'Cleopatra', 'Sunki × English', 'Volkameriano', 'Webberi' y 'Yuma'. Las plantas fueron establecidas en el año 2001, se evaluaron por 10 años (2004-2013) las variables de crecimiento vegetativo, rendimiento y calidad de fruta. 'Sunki × English' y 'Volkameriana' fueron los patrones con más alto rendimiento de fruta, el menor fue 'Yuma'. Todos los patrones, excepto 'Yuma' estabilizaron su altura en el último año. En volumen 'Amblycarpa' y 'Cleopatra' produjeron las plantas más grandes, y 'Yuma' el más pequeño. El patrón con mejor eficiencia de copa es 'Yuma' seguido por 'Sunki × English'. Todos los patrones presentaron frutas de calidad similar, excepto por 'Sunki × English' el cual obtuvo una relación alta de sólidos solubles totales/acidez total titulable.

**Palabras clave:** ecofisiología, calidad de la fruta, genotipo, propagación, *Citrus*.

## Introduction

The production of citrus is possible in tropical and subtropical zones and tropical zones are located between 23.5° North and South latitude. In addition, citrus is cultivated between 0 and 2,000 m a.s.l. (Orduz-Rodríguez *et al.*, 2011) and is produced in tropic highlands (1,500-2,000 m a.s.l.), medium lands (800-1,500 m a.s.l.) and lowlands (0-700 m a.s.l.) (Orduz-Rodríguez, 2007). However, 'Valencia' sweet oranges offer the best economic performance in citrus fruits for tropic lowlands (Mateus *et al.*, 2010) and are classified as a late harvest crop (Davies and Jackson, 2009). In tropical lowland conditions, plants reach bigger sizes than in subtropical and tropical conditions (Reuther, 1977).

Under tropical conditions, the flowering intensity, duration and distribution are due to water stress (Davenport,

1990). Furthermore, the fruit growth is fast with a poor external quality, green rind, pallid yellow colored fruit, and low total soluble solids and total titratable acid due to the fact that the average temperature remains high all year, causing high respiratory rates that metabolize sugars and acids (Davies and Albrigo, 1994).

The evaluation of rootstock is vital for the commercial development of citrus crops due to the fact that the rootstock affects more than 20 horticultural variables of citrus plants (Davies and Albrigo, 1994), including yield. This kind of investigation must be done locally, according to the plant response to the weather, soil, disease and crop management (Wutscher and Bistline, 1988). As a result, the response of the rootstocks to the mentioned variables could improve the actual productive capacity of the 'Valencia' sweet orange trees grafted over the 'Cleopatra' tangerine that has been

Received for publication: 5 February, 2015. Accepted for publication: 30 March, 2015.

Doi: 10.15446/agron.colomb.v33n1.49497

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used due to its resistance to *Phytophthora* (Castle, 1987). 'Cleopatra' is classified as a rootstock with a late production entrance. In the end, selecting new rootstocks and understanding the productive, vegetative and fruit quality behavior provide information for making decisions about yield, field distribution and quality of fruit according to market demands.

## Materials and methods

The study was conducted in the equatorial lowland tropics at the Corpoica La Libertad Research Center (04°03' N, 73°29' W) in Villavicencio (Colombia), during 2001-2014. For this purpose, the following rootstocks were studied: 'Amblycarpa' (*Citrus amblycarpa* [Hassk.] Ochse), 'C-35' (*Citrus sinensis* [L.] Osb. × *Poncirus trifoliata* [L.] Raf.), 'Carrizo' (*Citrus sinensis* [L.] Osb. × *Poncirus trifoliata* [L.] Raf.), 'Swingle' citrumelo or CPB 4475 (*Citrus paradisi* Macfad. × *Poncirus trifoliata* [L.] Raf.), 'Cleopatra' (*Citrus reshni* hort. ex Tanaka), 'Sunki × English' (*Poncirus trifoliata* [L.] Raf. × *Citrus sunki* [Hayata] hort. ex Tanaka), 'Volkamer' (*Citrus limmonia* Osbeck), 'Webberi' (*Citrus webberii* Wester), and 'Yuma' (*Citrus sinensis* [L.] Osb. × *Poncirus trifoliata* [L.] Raf.). The rootstocks were propagated from mother plants located at the Corpoica Palmira Research Center in Palmira (Colombia), and, after one year, the plants were grafted using inverted T-bud with 'Valencia' sweet orange (*Citrus sinensis* [L.] Osbeck) bud. The budded plants were planted with a distance of 8 × 5 m using a randomized complete block design and the soil type was classified as Typic haplustox. For which, the texture components were 59.5% sand, 14.00% loam, and 26.5% clay, and the soil pH was 4.5. In addition, the experiment was surrounded by 'Valencia' sweet orange grafted over 'Cleopatra' rootstock, the soil surface was covered with

forage peanut and weeds, and the plants were not irrigated. Lastly, the management of the crop was done according to the recommendations of Orduz-Rodríguez and Baquero (2003) for citrus on the Colombian eastern plains.

The fruits were collected and weighed every year, 2005-2014, for each tree as the result of flowering intensity of the corresponding year. Also, the information for plant growth was taken annually in the dry season between December and February, and the canopy volume was calculated using the Turrel (1946) formula,  $v = 0.5236 \times H \times D$ , where H is high and D is diameter. Furthermore, the yield efficiency index was calculated as the production/canopy volume, expressed as kg m<sup>-3</sup>, and fruit quality data from November to January were estimated from a sample of ten fruits for each rootstock per block; from this, the average fruit weight, total titratable acidity (TTA), total soluble solids (TSS), average juice percentage age, and TSS/TTA ratio were obtained. Each fruit was weighed and the juice was extracted with an electric squeezer. Then, the juice content was sized with a graduated pipet. Finally, the total soluble solids was determined with a Brixco handheld refractometer (Atago, Tokyo) and the total titratable acidity as the citric acid equivalent was measured by titration with 0.1 N NaOH.

All of the data were subjected to ANOVA and the mean comparison to a Tukey multiple range test. Proc GLM was used for the statistics SAS® v.9.3.

## Results

### Fruit yield

Fruit production started in the third year, except for 'Webberi' and 'Cleopatra', with the first harvest in the fourth year, and the production stabilized in the sixth year for

**TABLE 1.** Annual and cumulative fruit yield (kg/plant) for 'Valencia' sweet orange plants grafted on nine rootstocks from 2004 to 2013. La Libertad Research Center, Villavicencio (Colombia). Plants established in 2001.

Rootstock	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Cumulative
'Sunki × English'	7.69 ab	11.19 b	51.15 a	75.68 ab	153.44 bc	70.96 a	146.28 a	138.36 a	89.84 a	197.74 ab	942.33 a
CPB 4475	6.47 ab	17.71 b	29.19 b	50.28 ab	92.56 d	27.03 b	76.07 bcd	46.66 bcd	75.88 a	114.20 d	536.05 c
'C-35'	2.94 bc	17.04 b	20.95 b	47.15 ab	106.20 cde	30.65 b	77.32 bcd	50.03 cd	89.58 a	139.16 cd	581.02 bc
'Yuma'	1.13 bc	10.66 b	15.33 b	31.00 b	49.95 e	22.25 b	56.76 d	20.64 d	53.89 a	66.20 de	327.81 d
'Amblycarpa'	1.87 ab	3.71 b	11.80 b	50.09 ab	104.40 cde	30.18 b	72.16 cd	55.27 bcd	102.62 a	278.34 a	710.45 bc
'Carrizo'	4.17 bc	16.30 b	29.38 b	66.17 ab	113.22 cde	47.53 ab	54.73 cd	91.40 b	71.19 a	131.91 c	626.00 bc
'Cleopatra'	0.40 ab	3.91 b	27.81 b	60.77 ab	203.47 ab	37.33 b	99.45 bcd	66.78 bcd	66.23 a	158.41 bcd	724.56 ab
'Volkamer'	4.23 bc	43.17 a	62.11 a	80.93 ab	234.81 a	69.10 a	84.82 bcd	79.97 bc	62.28 a	149.25 bcd	870.67 a
'Webberi'	0.93 bc	4.28 b	27.62 b	60.00 ab	144.62 bcd	40.34 b	111.88 ab	86.70 bc	95.55 a	201.68 abc	773.59 ab

Means with different letters in each column indicate significant differences according to the Tukey test ( $P \leq 0.05$ ).

the CPB 4475, C-35 -2007-. However, 'Carrizo', 'Sunki × English' and 'Volkamer' lemon stabilized their production in the 2006 fifth year with a production of 29.38, 51.15 and 62.11 kg/plant, respectively (Tab. 1). Finally, 'Yuma' was the last one to stabilized production, in 2008 with 49.95 kg/plant.

For the cumulative production, 'Sunki × English' was the rootstock that had the highest (942.34 kg/plant), followed by 'Volkamer' lemon (870.67 kg/plant) without significant differences. 'Yuma' showed the lowest cumulative production with (327 kg/plant).

## Plant growth

### Height

'Volkamer' lemon showed higher plants in the field during the years 2005-2009. However, the 'Yuma' plants had the lowest height. In the last three periods of the evaluation

(2010-2012), all of the rootstocks showed the same behavior in terms of height, with no significant differences except for 'Yuma', which showed the lowest value with 2.81 m for 2012 (Tab. 2).

### Canopy volume

Table 3 shows the canopy volume values; 'Cleopatra' and 'Amblycarpa' were the better rootstocks in the last evaluation with canopy volumes of 43.71 and 43.62 m<sup>3</sup>; in the middle position were the other rootstocks, except 'Yuma', which registered the lowest volume value (13,5 m<sup>3</sup>) of 2012.

### Yield efficiency

'Yuma' was the best rootstock for the average yield efficiency (7.02 kg m<sup>-3</sup>), followed by 'Sunki × English' (6.50 kg m<sup>-3</sup>) without significant differences. On the other hand, 'Cleopatra' was the lowest rootstock (3.48 kg m<sup>-3</sup>), with 'Carrizo', 'Webberi', 'C-35', CPB 4475, 'Volkamer' and 'Amblycarpa' in the middle group, between 5.20 and 3.78 kg m<sup>-3</sup> (Tab. 4).

**TABLE 2.** Plant height of 'Valencia' sweet oranges grafted on nine rootstocks from 2005 to 2012. La Libertad Research Center, Villavicencio (Colombia). Plants established in 2001.

Rootstock	2005	2006	2007	2008	2009	2010	2011	2012
'Amblycarpa'	2.07c	2.68c	2.94b	3.12bc	3.08bcd	3.92ab	4.06ab	3.97a
'C-35'	2.11c	2.53c	2.66bc	2.83cd	2.8375d	3.48b	3.61b	3.78a
'Carrizo'	2.31bc	2.74c	2.85b	2.76d	2.86dc	3.38b	3.5b	3.65a
CPB 4475	2.4b	2.79c	2.97b	3.29b	2.93dc	4.06a	3.71a	3.69a
'Cleopatra'	2.5b	3.13b	3.33ab	3.32b	3.28ab	4.07a	4.1a	4.12a
'Sunki × English'	2.41b	2.94bc	2.81b	3.23b	3.19abc	3.84ab	3.81ab	3.56a
'Volkamer'	2.79a	3.59a	3.73a	3.67a	3.49a	3.99ab	4.07ab	4.18a
'Webberi'	2.36bc	2.71c	2.87b	2.85c	2.78d	3.59ab	3.86ab	3.93a
'Yuma'	1.77d	2.09d	2.27c	2.25e	2.09e	2.71c	2.78c	2.81b

Means with different letters in each column indicate significant differences according to the Tukey test ( $P \leq 0.05$ ).

**TABLE 3.** Canopy volume (m<sup>3</sup>) of 'Valencia' sweet oranges grafted on nine rootstocks from 2005 to 2012. La Libertad Research Center, Villavicencio (Colombia). Plants established in 2001.

Rootstock	2005	2006	2007	2008	2009	2010	2011	2012
'Amblycarpa'	2.00 cd	5.16 d	8.19 c	13.29 c	47.78 a	26.03 b	37.32 a	43.62 a
'C-35'	2.28 cd	5.22 cd	7.51 c	11.85 c	13.43 a	20.00 b	23.19 b	27.58 b
'Carrizo'	3.78 bc	7.55 bc	9.05 bc	12.25 c	14.99 a	21.34 b	23.02 b	28.21 b
CPB 4475	3.38 bc	6.37 c	9.50 bc	16.31 bc	20.29 a	29.02 ab	30.82 ab	25.11 bc
'Cleopatra'	4.03 b	9.87 b	14.28 b	19.41 b	24.05 a	33.93 ab	37.38 a	43.71 a
'Sunki × English'	3.67 b	9.19 bc	11.73 bc	18.95 b	20.89 a	29.80 ab	30.14 ab	30.72 ab
'Volkamer'	6.67 a	14.68 a	19.77 a	25.99 a	25.50 a	35.17 a	33.23 a	37.82 ab
'Webberi'	2.32 bcd	6.28 c	9.20 bc	14.64 bc	15.25 a	23.78 b	28.7 ab	35.41 ab
'Yuma'	1.14 d	2.54 d	3.91 c	5.22 d	5.90 a	8.91 c	8.70 c	13.50 c

Means with different letters in each column indicate significant differences according to the Tukey test ( $P \leq 0.05$ ).

**TABLE 4.** Yield efficiency (kg m<sup>-3</sup>) of 'Valencia' sweet oranges grafted on nine rootstocks from 2005 to 2012. La Libertad Research Center, Villavicencio (Colombia). Plants established in 2001.

Rootstock	2005	2006	2007	2008	2009	2010	2011	2012	Average
'Amblycarpa'	0.87 a	2.16 b	8.15 a	7.17 a	2.00 a	2.25 b	1.84 b	1.96 b	3.78 bc
'C-35'	7.49 a	5.09 ab	6.90 a	8.25 a	2.28 a	3.89 ab	2.20 b	3.48 ab	4.53 bc
'Carrizo'	3.88 a	5.06 b	6.78 a	9.79 a	3.43 a	2.92 b	4.41 ab	2.83 ab	5.20 b
CPB 4475	6.3 a	7.11 ab	6.45 a	6.06 a	1.82 a	2.99 ab	1.67 b	2.27 b	4.32 bc
'Cleopatra'	0.6 a	2.99 b	5.53 b	11.69 a	1.46 a	2.69 b	1.62 b	1.42 b	3.48 c
'Sunki × English'	4.4 a	6.7 ab	9.05 a	9.98 a	3.94 a	5.69 a	5.96 a	2.59 b	6.50 ab
'Volkamer'	7.9 a	4.15 b	4.96 b	8.35 a	2.85 a	2.52 b	2.37 b	2.11 b	4.00 bc
'Webberi'	2.33 a	4.27 b	8.16 a	10.71 a	2.48 a	4.55 ab	3.09 b	3.04 ab	5.05 bc
'Yuma'	6.11 a	10.83 a	8.15 ab	9.53 a	4.48 a	3.58 ab	3.02 b	4.18 a	7.02 a

Means with different letters in each column indicate significant differences according to the Tukey test ( $P \leq 0.05$ ).

## Fruit quality

The data for fruit quality were taken during the main harvest period in the years from 2009 to 2012.

'Carrizo' and 'Yuma' gave the higher fruit weights (229.08 - 228.28 g), without statistical differences, and 'Webberi' 'Amblycarpa' 'C-35' and 'Cleopatra' showed intermediate fruits with weights between 227.63 and 218.83 g (Tab. 5). Furthermore, the rootstocks with a higher TSS were 'Sunki × English' and 'C-35', both with 10.44%, followed by 'Amblycarpa', 'Carrizo', CPB 4475 and 'Volkamer' in a range of 10.38 to 9.95%; in the last group, there were 'Cleopatra', 'Webberi' and 'Yuma' (9.76-9.38%). However, the TTA variable did not have significant differences between the rootstocks. In the maturity index (TSS/TTA), 'Sunki × English' was on top (15.82%); differences were only seen with 'Volkamer' (11.44%), 'Webberi' (12.51%), 'Yuma' (12.85%) and 'Cleopatra' (13.19%). Lastly, 'Volkamer' lemon had the fruits with the highest juice percent per fruit (46.72%) and the lowest juice percent was obtained by 'Webberi' (38.90%) (Tab. 5).

## Discussion

'Sunki × English' was the rootstock with the best production behavior, over the commonly used 'Cleopatra'. In 'Folha murcha' sweet orange, 'Sunki' had a middle production rootstock. However, 'Citrumelo' had a higher production than 'Sunki', but they were not significantly different. The differences between the current experiment and Cantuarias-Avilés *et al.* (2011) came about because 'Sunki' was a hybrid in the current study. On the other hand, 'Cleopatra' showed a late entrance for picking, as described by Castle (1987), and a good yield, contrary to Pérez-Pérez *et al.* (2010), who reported on 'Lane late' navel oranges, where 'Cleopatra' had a lower yield than 'Carrizo'. Furthermore, 'Yuma' had the lowest rootstock yield due to the fact that the plants were smaller in height and volume, as opposed to 'Volkamer', which was one of the rootstocks with a higher yield and bigger plants. This behavior was similar in 'Shamouti' orange (Georgiou and Gregoriou, 1999). Also, the stabilization of the rootstocks in terms of height in the last two years of evaluation

**TABLE 5.** Fruit quality (average of five years 2008-2012) of 'Valencia' sweet oranges grafted on nine rootstocks. La Libertad Research Center, Villavicencio (Colombia). Plants established in 2001.

Rootstock	Fruit weight (g)	TSS (%)	TTA (%)	Index TSS/TTA	Juice percentage
'Amblycarpa'	226.64 ab	10.38 ab	0.70 a	14.83 ab	43.41 ab
'C-35'	224.89 ab	10.44 a	0.76 a	13.74 ab	42.37 b
'Carrizo'	229.08 a	10.07 ab	0.70 a	14.39 ab	44.27 ab
CPB 4475	212.42 b	10.03 ab	1.39 a	13.2 ab	44.70 ab
'Cleopatra'	218.83 ab	9.76 b	0.74 a	13.19 b	41.39 b
'Sunki × English'	216.72 b	10.44 a	0.66 a	15.82 a	44.16 ab
'Volkamer'	215.52 b	9.95 ab	0.87 a	11.44 b	46.72 a
'Webberi'	227.63 ab	9.38 b	0.75 a	12.51 b	38.90 b
'Yuma'	228.28 a	9.64 b	0.75 a	12.85 b	40.82 b

Means with different letters in each column indicate significant differences according to the Tukey test ( $P \leq 0.05$ ).

showed a dominance of the 'Valencia' sweet orange over the rootstock, except for 'Yuma' (Tab. 2). 'Volkamer' and 'Cleopatra' had the higher trees. This behavior is common even if the localities change as Castle *et al.* (2010) showed in a study of 12 rootstocks in 'Valencia' sweet orange. Furthermore, 'Cleopatra' and 'Amblycarpa' produced bigger canopy volumes than 'Volkamer'; in an assay by Forner-Giner *et al.* (2003), this behavior was similar in 'Navelina' oranges grafted over hybrids of 'Cleopatra' and 'Volkamer' lemon. However, 'Yuma' had the smallest canopy volume, even lower than 'Carrizo' (Tab. 3), whereas 'Carrizo' is characterized as having a canopy volume similar to that of 'Yuma' in 'Lapithkiotiki' lemon (Georgiou, 2009). This difference could have resulted from a the lack of adaptation in 'Yuma' to acid soil conditions, as evidenced by a marked chlorosis. In spite of this, 'Yuma' was the rootstock with the highest yield efficiency, followed by 'Sunki × English' with trees that were double in size. 'Sunki × English' has been described as a high yield efficiency rootstock in 'Arrayana' tangerine (Orduz-Rodríguez *et al.*, 2006) in tropic lowlands. Nonetheless, the fruit quality variables did not show major differences between the rootstocks, except for the maturity index (TSS/TTA). 'Sunki × English' had the best ratio and the other hybrids of 'Sunki' grafted on 'Marsh' grapefruit also obtained a higher ratio (Castle *et al.*, 2010). In contrast, Uribe-Bustamante *et al.* (2013) found that the best rootstock for fruit quality in 'Valencia' sweet oranges was Sour orange, followed by 'Cleopatra' and 'Yuma'.

## Conclusion

The results revealed that 'Sunki × English' and 'Volkamer' proved to be the better rootstocks for a high yield of 'Valencia' sweet oranges. Furthermore, 'Yuma' cannot be used in tropical lowlands even if the number of plants per hectare is increased.

## Acknowledgements

Thanks to Colciencias for promoting the young researchers program; to the Corpoica group for the fruits in La Libertad Research Center; and to Diana Mateus, Nadia Pineda, David Hernandez, Alfredo Pardo, Capitolino Ciprian, without their help this study would not have been possible.

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