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CHARACTERIZATION OF 'VALENCIA LATE' ORANGE ON DIFFERENT ROOTSTOCKS, IN "ENTRE RÍOS", ARGENTINA

Caracterización de naranjo 'Valencia Late' sobre diferentes portainjertos en "Entre Ríos", Argentina

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ABSTRACT. In fruit production, rootstocks are used to control factors such as plant height, resistance to pests and diseases and production earliness. The aim of this study was to evaluate size, production and production efficiency of 'Valencia Late' orange [*Citrus sinensis* (L.) Osbeck] plants over different rootstocks, grouping them according to these characteristics and define the most efficiency rootstocks for the studied region. Field data was collected between 1994 and 2010, from 'Valencia Late' orange plants, grafted on seventeen different rootstocks, with a density of 333 plants per hectare in "Entre Ríos", Argentina. During all seasons, growth variables (plant height, crown diameter, trunk diameter and standing) and production per plant were recorded. Also canopy volume and production efficiency were determined. To describe the production and growth variables and to identify rootstocks groups according to plants size, production and production efficiency, Principal Component Analysis, Biplot graph and Multivariate Analysis of Variance and Hotelling test were applied. Three groups of rootstocks could be identified: the first group with larger plants, higher production but lower production efficiency; the second group, with an intermediate behavior and the third group, with smaller plants, lower production but higher production efficiency. Rootstocks of the third group showed more efficiency, can be recommended for the studied region with higher density of planting.

Key words: fruit, plants, height, production, productive efficiency

RESUMEN. El uso de portainjertos es una estrategia de producción en cultivos frutales, orientada a controlar factores como porte de la planta, resistencia a plagas y enfermedades, precocidad en el ingreso a producción. Este trabajo tuvo como objetivos: evaluar el tamaño, la producción y la eficiencia productiva de plantas de naranjo 'Valencia Late' [*Citrus sinensis* (L.) Osbeck] sobre diferentes portainjertos, clasificarlos y determinar cuáles inducen plantas más eficientes para la región. La información de campo se obtuvo entre las campañas 1994 y 2010, en ensayos de naranjo 'Valencia Late' injertado sobre 17 portainjertos diferentes, con 333 plantas por hectárea, en "Entre Ríos", Argentina. Se registró la producción, se midieron variables de crecimiento (altura de planta, diámetro de copa, diámetro de tronco por encima y por debajo del injerto) y se calculó el volumen de copa y la eficiencia productiva. Para describir el comportamiento de las variables de crecimiento y de producción e identificar grupos de portainjerto, según el tamaño de las plantas, la producción y la eficiencia productiva, se realizó Análisis de Componentes Principales, gráfico Biplot, Análisis de la Varianza Multivariado y prueba de Hotteling. Se pudieron identificar tres grupos de portainjertos; el primero incluyó plantas de mayor porte, mayor producción pero menor eficiencia productiva; el segundo, con plantas de tamaño y productividad intermedia y el tercero, con plantas de pequeño porte y mayor eficiencia productiva. Los portainjertos del tercer grupo demostraron ser más eficientes y pueden ser recomendados para la región en estudio con mayores densidades de plantación.

Palabras clave: frutales, plantas, producción, eficiencia productiva

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INTRODUCTION

The use of rootstocks has become a strategy in fruit crops, it is oriented to control tree size, resistance to pests and diseases and production earliness (1).

The election of the most adequate rootstock greatly depends on the influence of the environment on plants behavior. The ideal rootstock does not exist because there are many factors affecting its behavior (plant vigor development, production, fruit quality, adaptability to the environment, relations with soil features) and mainly, its relations to the grafted scion (2).

Several authors have described the behavior of different rootstocks on several citrus species. One of them is a study on plant growth and the development of ‘Tahití’ lime (*Citrus latifolia* Tan.) fruits on four rootstocks planted in a grove in the State of Lara, Venezuela. This study determined that rootstocks like ‘Volkamer’ lemon [*Citrus volkameriana* (Pasq.)] and ‘Amblycarpa’ [*Citrus amblycarpa* (Hassk.) Ochse] induced higher plants, canopy diameter, side surface and canopy volume than ‘Cleopatra’ mandarin [*Citrus reshni* (Hort.) ex Tan.] ‘Swingle’ citrumelo [*Poncirus trifoliata* (L) Raf.] *x* [*Citrus paradisi* (Macf.)] (3).

In Persian limes, it was found that ‘C35’, ‘Florida’, ‘Carrizo’, ‘C32’, ‘Benton’ and, ‘Morton’ citranges, mandarins like ‘Cleopatra’ and ‘Amblycarpa’, ‘Volkamer’ lemon and ‘Sour’ orange induced higher plants, while ‘Volkamer’ lemon, ‘Cleopatra’ and ‘Amblycarpa’ produced lower trunk diameters (4). In eleven years old ‘Persian’ limes trees grafted on ‘Carrizo’ citrange [*Citrus sinensis* (L.) Osb.] *x* trifoliate [*P. trifoliata* (L.) Raf.], ‘Swingle’ citrumelo [*P. trifoliata* (L) Raf.] *x* [*C. paradisi (*Macf.)], ‘Volkamer’ lemon [*C. volkameriana* (Pasq.)] and ‘Rough’ lemon [*Citrus jambhiri* (Lush.)], it was found that ‘Rough’ lemon produced higher plants, higher canopy volume and fruit yield, however, productive efficiency was similar to ‘Carrizo’ citrange and ‘Swingle’ citrumelo (5).

In ‘Valencia’ orange on hybrids of trifoliate orange [*P. trifoliata* (L) Raf.], it was found that grafted plants on the hybrids ‘Sunki’ *x* ‘English’ citrandarin and ‘Troyer’ citrange were the most productive ones and citrandarins ‘Clementina’ x trifolio, ‘Cleopatra’ x ‘Swingle’ and ‘Cleopatra’ x ‘Christian’ induced smaller plants (6). In ‘Valencia’ orange grafted on citrumelos, ‘Rangpur’ lime and citremon, the highest values of productive efficiency were recorded in smaller plants grafted on some lines of citrumelo that induced lower canopy volumes (7). Fruit production, tristeza susceptibility, tree decline and the scion-rootstock incompatibility in ‘Valencia’ orange grafted on 10 trifoliate hybrids and ‘Rangpur’ lime, showed that citrandarins ‘Sunki’ *x* ‘English’, ‘Changsha’ *x* ‘English Small’, ‘Cleopatra x English’ and ‘Cleopatra x Rubidoux’ and ‘Pera’ citrange x trifoliate provided similar fruit production values to those reached with ‘Swingle’ citrumelo and higher than those attained with ‘Rangpur’ lime (8). Also in ‘Valencia’ orange on ‘Volkamer’ lemon [*C. volkameriana* (Ten. & Pasq.)], ‘Cleopatra’ mandarin [*C. reshni* (Hort.) ex Tan.] and ‘Amblycarpa’ [*C. amblycarpa* (Hassk.) Ochse], it was found that plants on ‘Volkamer’ lemon and ‘Amblycarpa’ were higher than those on ‘Cleopatra’ (9).

In the region that hosted this study most citrus groves use [*Poncirus trifoliata* (L.) Raf.] as rootstock. The general use of only one rootstock is a risk to the emergence of diseases or productive problems. In order to avoid this, it is necessary to find alternative rootstocks, testing new materials and the selection of those or promising behavior adapting to the existing conditions, that allow to increase productivity, reduce tree size and provide tolerance to diseases, among others.

The objectives of this research have been characterizing sweet orange trees [*Citrus sinensis* (L.) Osbeck] cultivar ‘Valencia Late’, on different rootstocks and classifying rootstocks according to tree height and the productive efficiency induced.

MATERIALS AND METHODS

Biological material

Field data was provided by the Agricultural Experiment Station of the National Institute of Agricultural Technology in Concordia, Entre Ríos, Argentina, located at 152 masl and coordinates: 31° 22’27.64” S and 58° 07’01.41” W. The trial plot had 0,35 hectares on a sandy soil of the serie Yuquerí Grande, that belongs to the family of Cuarzisamentes óxicos ácuicos[A], where sweet orange seedlings were planted [*Citrus sinensis* (L.) Osbeck], cultivar ‘Valencia Late’ on 17 different rootstocks described on Table I. The spacing used was 5 m x 6 m, which is equivalent to a planting density of 333 trees per hectare.

Treatments were randomly selected. There were six replicates of one plant per rootstock. The planting year varied according to the rootstock. Rootstocks P3 and P15 in 1990, rootstocks P1, P4, P5, P6, P7, P8, P14, P16 and P17 in 1992 and P2, P9, P10, P11, P12 and P13 in 1994.

[A] Subsecretaría de Asuntos Agrarios. *Carta de Suelos de la República Argentina*, Instituto Nacional de Tecnología Agropecuaria, Departamento de Concordia, Provincia de Entre Ríos, 1993.

Table I. Description of studied rootstocks

Rootstock	Description
P1	'Cleopatra' tangerine [*Citrus reshni* (Hort.) ex Tan.] x trifoliate [*Poncirus trifoliata* (L.) Raf.]
P2	'Volkamer' lemon [*C. volkameriana* (Ten.) & Pasq.] x 'Carrizo' citrange (*C. sinensis* (L.) Osbeck x trifoliate (*P. trifoliata* (L.) Raf.)
P3	'Ruby Blood' orange [*C. sinensis* (L.) Osbeck] x trifoliate 'Barnes' [*P. trifoliata* (L.) Raf.]
P4	'Cleopatra' tangerine [*C. reshni* (Hort.) ex Tan.] x trifoliate USDA [*P. trifoliata* (L.) Raf.].
P5	'Cleopatra' tangerine [*C. reshni* (Hort.) ex Tan.] x 4475 citrumelo [*C. paradisi* (Macf.)] x [*P. trifoliat*a (L.) Raf.]
P6	'Ruby Blood' orange [*C. sinensis* L.) Osbeck] x trifoliate USDA [*P. trifoliata* (L.) Raf.]
P7	'Triumph' grapefruit [*Citrus paradisi* (Macf.)] x 'Troyer' citrange [*C. sinensis* (L.) Osbeck] x trifoliate [*P. trifoliata* (L.) Raf.]
P8	'Rangpur' lime [*C. limonia* (Osb.)] x 'Troyer' citrange [*C. sinensis* (L.) Osbeck] x trifoliate [*P. trifoliata* (L.) Raf.]
P9	'Cleopatra' tangerine [*C. reshni* (Hort.) ex Tan.] x trifoliate 136 [*P. trifoliata* (L.) Raf.]
P10	Limón 'Volkameriano' [*C. volkameriana* (Ten.) & Pasq.] x trifoliate USDA [*P. trifoliata* (L.) Raf.]
P11	'Volkamer' lemon [*C. volkameriana* (Ten.) & Pasq.] x 'Cleopatra' mandarin [*C. reshni* (Hort.) ex Tan.]
P12	'Sunky' tangerine [*C. sunki* (Hort.) ex Tan.] x 'Swingle' citrumelo [*P. trifoliata* (L.) Raf.] x [*C. paradisi* (Macf.)]
P13	'Sunky' tangerine [*C. sunki* (Hort.) ex Tan.] x trifoliate [*P. trifoliata* (L.) Raf).]
P14	'Benton' citrange [*C. sinensis* (L.) Osbeck] x trifoliate [*P. trifoliata* (L.) Raf.]
P15	4475 citrumelo [*C. paradisi* (Macf.)] x [*P. trifoliata* (L.) Raf.]
P16	Gou tou (*)
P17	'Mineola' tangelo [*C. reticulata* (Blanco)] x [*C. paradisi* (Macf.)] x trifoliate [*P. trifoliata* (L.) Raf.]

(*) Rootstock P16 is considered a spontaneous hybrid of sour orange **(10)**

Analyzed variables

From 1994 to 2010, in each season at the beginning of the harvest, production was quantified (Pr; kg/planta^{-1}) with a scale of up to 200 kg the following growth variables were evaluated: Plant height (AP; m), a graduate rule (cm) was used, it was placed at the North side of each plant; canopy diameter (DC; m), with a measuring tape perpendicular to the planting line; trunk diameter 10 cm above the bud union (DT; cm) and 10 cm below the bud union (DPi; cm) from West to East.

Canopy volume was calculated from measured variables (VC; m^3), by the formula (11): Vol = 0,5236 * H * D^2, where H is the plant height and D is the canopy diameter; and productive efficiency: Ef (kg m^{-3}) = Pr.VC^{-1} that represents production in kgs per unit of canopy volume.

Statistical analysis

All analyses took into account the stable production period of the trees, so data from 2003 to 2010 (seven years) were used. Each study year gathered information from 17 rootstocks, with six replicates each for a un total of 714 observations per variable.

In order to describe the joint behavior of growth and production variables and identify groups of rootstocks, a Main component analysis (ACP) and a Biplot graphic were used to represent the first two components on cartesian axis (12). The election of the number of components was made to preserve a minimum of 80 % of the total variability and include growth and production variables, and for the election of those more contributing variables within each component, a limit value of 80 % of the highest coefficient for that component, was taken. The evaluation of differences among detected groups by ACP andl Biplot, was done through a multivariate analysis of variance and then with Hotelling's test, with a signification level of (p≤0,05). Statistical analyses were done with the software InfoStat (13).

RESULTS AND DISCUSSION

Main Component Analysis and Biplot

The Biplot graphic (Figure 1) shows the first two components resulting from ACP. These two components explain the 86 % of the total variability among observations (13). It indicates the reduction to two dimensions that permit watching variables and rootstocks on a plane: It is done only losing 14 % of the original information variability.

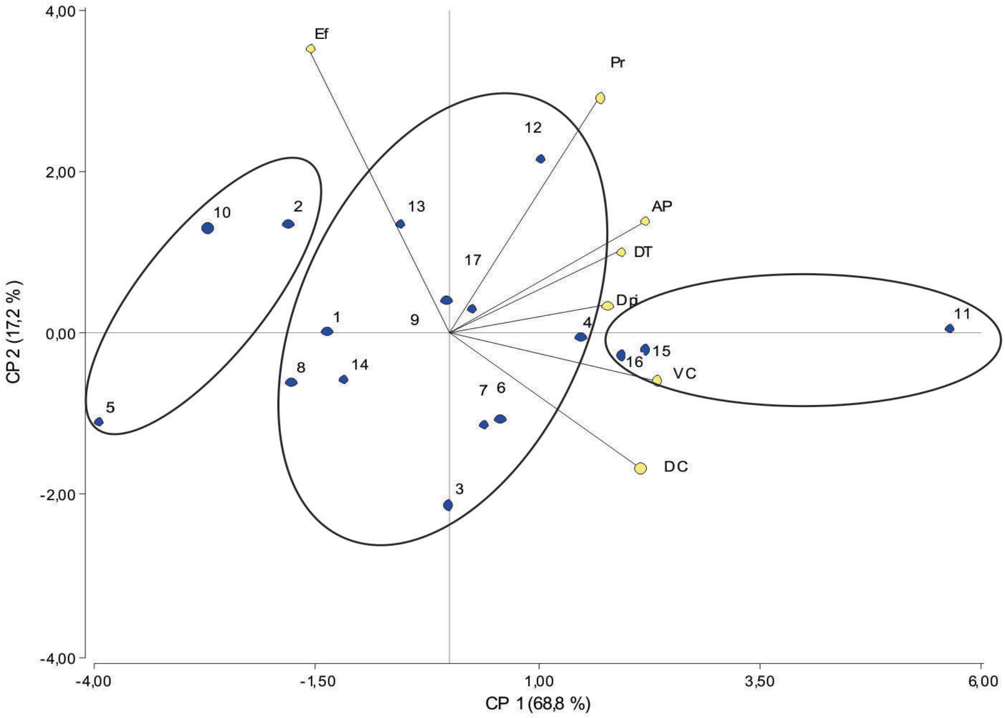

Figure 1. Biplot according to ACP, indicating groups of rootstocks of growth variables (AP, DC, VC, DT, DPi), production and yield (Ef). (n=714)

The self-value associated to the first component (CP1) was 0,688; it indicates that this component explains the 68,8 % of the total variability and its mathematical expression is given by: CP1= 0,45 (VC) + 0,42 (AP) + 0,41 (DC) + 0,37 (DT) + 0,34 (Pr) + 0,32 (DPi) - 0,30 (Ef).

According to the absolute values of the coefficients, the major variables in the definition of CP1 are: VC, AP, DC and DT. It would indicate that the defined axis for CP1, mainly separates rootstocks by tree size, with higher plants to the right and smaller plants to the left.

The self-value associated to the second component (CP2) was 0,172; indicating that this component explains the 17,2 % of the total variability, its mathematical expression is given by: CP2= 0,68 (Ef) + 0,56 (Pr) - 0,32 (DC) + 0,27 (AP) + 0,19 (DT) - 0,11 (VC) + 0,07 (DPi).

The major coefficients belong to Ef andy Pr, indicating that the second axis separates rootstocks mainly by these variables. With Ef and Pr reduction from upper quadrants to lower quadrants.

Taking into account the axis generated by both components, Figure 1 makes possible to identify three groups of rootstocks. Group 1, to the right, formed by higher plants with higher production, but with less productive efficiency, it includes rootstocks like P11, P15 and P16. Group 2, in the middle, made up of plants showing intermediate values in all variables, it includes rootstocks P1, P3, P4, P6, P7, P8, P9, P12, P13, P14 and P17. Group 3, to the left, composed of rootstocks P2, P5 and P10, it is characterized by lower plants withf less production, but with a higher productive efficiency.

Figure 1. Biplot according to ACP, indicating groups of rootstocks of growth variables (AP, DC, VC, DT, DPi), production and yield (Ef). (n=714)

Multivariate Analysis of Variance and Hotelling's Test

Table II, shows every studied variable, average values by each rootstock group defined by ACP and Biplot, and detected deficiencies among them.

Medium factors by group reflect that, except efficiency, Group 1 had higher values in all variables, both size and production wise, with a tendency to decrease from Group 1 to Group 3. Inversely, efficiency increased in the same sense.

Table II. Results of the Hotteling's test among rootstocks groups

Grupo	AP (m)	DC (m)	VC (m3)	DT (cm)	DPi (cm)	Pr (kg plant^{-1})	Ef (kg m3 canopy^{-1})	(*)
1	3,35	3,84	26,65	16,54	26,23	100,75	3,95	C
2	2,87	3,41	17,84	13,69	20,23	83,76	4,95	B
3	2,57	2,87	11,16	12,87	17,58	69,32	6,53	A

(*) Different letters mean significant differences (p≤ 0,05)
Plant average height (AP), canopy diameter(DC), canopy volume (VC), trunk diameter (DT), rootstock diameter (DPi), production (Pr) and productive efficiency (Ef)

Characterization of rootstocks according to formed groups

Group 1

The results of this study point out that the rootstocks of this group produce vigorous and high plants, but with less productive efficiency. This group is made up of: 'Volkamer' lemon x 'Cleopatra' mandarin (P11), 4475 citrumelo (P15) and Gou tou (P16).

These results coincide with reports from other authors that point out that 'Volkamer' lemon induces vigorous and high plants (14), they also coincide with the results of 'Tahití' lime (3), in which plants on 'Volkamer' lemon and 'Amblycarpa' showed higher trees than those grafted on 'Cleopatra' mandarin, 'Swingle' citrumelo and 'Persian' lime (4).

Such results also coincide for 'Valencia' orange, where 'Volkamer? Lemon and 'Amblicarpa' induced higher trees with higher canopy diameters than 'Cleopatra' mandarin (9) and in 'Lane Late' orange (*Citrus sinensis* L. Osb.), where the lowest productive efficiency value was found for Gou tou Chen (15). These results oppose those found in 'Valencia' orange in which citrumelo produced higher plants with higher productive efficiency than 'Rangpur' lime and citremon (7).

Group 2

Rootstocks included in this group showed intermediate values for all variables. It was made up of the following rootstocks: 'Cleopatra' mandarin x trifoliate (P1), 'Ruby Blood' orange x trifoliate 'Barnes' (P3), 'Cleopatra' mandarin x trifoliate 'USDA' (P4), 'Ruby Blood' orange x trifoliate USDA (P6), 'Triumph' grapefruit x 'Troyer' citrange (P7), 'Rangpur' lime x trifoliate (P8), 'Cleopatra' mandarin x trifoliate 136 (P9), 'Sunky' mandarin x 'Swingle' citrumelo (P12), 'Sunky' mandarin x trifoliate (P13), 'Benton' citrange x trifoliate (P14) y 'Mineola' tangelo x trifoliate (P17).

The results of these trials are similar to those found in 'Persian' limes in which the hybrid 'Carrizo' citrange x trifoliate induced smaller plants with lower yields compared to 'Rough' lemon (5), and in 'Valencia' orange where hybrid rootstocks from trifoliate produced small plants (6).

Group 3

This group has small plants with high productive efficiency values. It is composed of the following rootstocks: 'Volkamer' lemon x 'Carrizo' citrange (P2), 'Cleopatra' mandarin x 4475 citrumelo (P5) and 'Volkamer' lemon x trifoliate USDA (P10).

However, 'Volkamer' lemon induced vigorous and high plants, its hybrids with 'Carrizo' citrange and trifoliate induced small plants with a high productive efficiency. These results coincide with those reached in 'Valencia' orange (6), where hybrids 'Clementine' x trifoliate, 'Cleopatra' x 'Swingle' and 'Cleopatra' x 'Christian' induced small plants.

The rootstocks of the third group could be recommended for the studied region, however, their possibilities with planting densities higher than those used in this experiment would have to be explored.

CONCLUSIONS

Three groups of rootstocks were identified, the first one composed of Gou tou citrumelo and the hybrids 'Volkamer' lemon and 'Cleopatra' mandarin, characterized by inducing high plants with a low productive efficiency. The second group, with intermediate plants and production, made up of the trifoliate hybrids with mandarin, orange, grapefruit, citrange and tangelo. The third group included the hybrids of trifoliate and citrumelo with lemon or mandarin, that induced small plants with high productive efficiency.

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