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Pomology/ Original Article

Performance of 'Valência' sweet orange grafted onto rootstocks in the state of Acre, Brazil

Abstract – The objective of this work was to select rootstocks, based on the agronomic characters and fruit quality of the 'Valência' orange tree. The evaluated rootstocks were: the 'Cleópatra' mandarin; the TSKFL x CTTR-013, LVK x LCR-038, TSKC x CTQT 1439-004, LVK x LVA-009, TSK x TRENG-256 ('Indio' citrandarin) hybrid genotypes; the 'Santa Cruz' Rangpur lime; and the TSKFL x CTC-25-002, and TSKC x CTSW-038 hybrids. The experiment was installed in 2010 and evaluated from 2013 to 2017. The parameters plant height, canopy volume, yield efficiency, scion:rootstock ratio, survival percentage, and drought tolerance were evaluated in 2017. The yield average of five harvests was estimated, as well as the annual production per plant and the accumulated production. The analyzed fruit traits were: mass, diameter, peel length and thickness, juice yield, soluble solids, acidity, and technological index. 'Valência' shows a lower plant height and canopy volume, besides a higher yield efficiency, when grafted on TSKC x CTSW-038 than on the other rootstocks. LVK x LCR-038, TSKC x CTQT 1439-004, 'Indio' citrandarin, and 'Santa Cruz' Rangpur lime increase the production of the 'Valência' orange. LVK x LCR-038 and the 'Indio' citrandarin induce the scion to produce a better quality fruit.

Index terms: *Citrus*, *Poncirus trifoliata*, fruit quality, Rangpur lime, Western Amazon, yield.

Desempenho da laranjeira 'Valência' sobre porta-enxertos no Estado do Acre

Resumo – O objetivo deste trabalho foi selecionar porta-enxertos, com base nos caracteres agronômicos e na qualidade de frutos da laranjeira 'Valência'. Os porta-enxertos avaliados foram: a tangerina 'Cleópatra'; os híbridos TSKFL x CTTR-013, LVK x LCR-038, TSKC x CTQT 1439-004, LVK x LVA-009 e TSK x TRENG-256 (citrandarin 'Indio'); o limoeiro-cravo 'Santa Cruz'; e os híbridos TSKFL x CTC-25-002 e TSKC x CTSW-038. O experimento foi instalado em 2010 e avaliado de 2013 a 2017. Os parâmetros altura da planta, volume da copa, eficiência produtiva, relação entre copa e porta-enxerto, percentagem de sobrevivência e tolerância à seca foram avaliados em 2017. Foram estimadas a produtividade média de cinco safras, assim como a produção anual por planta e a produção acumulada. As características dos frutos analisadas foram: massa, diâmetro, comprimento e espessura de casca, rendimento de suco, sólidos solúveis, acidez e índice tecnológico. A 'Valência' apresenta menor altura de planta e volume da copa, bem como maior eficiência produtiva, quando enxertada sobre TSKC x CTSW-038 do que sobre os outros porta-enxertos. LVK x LCR-038, TSKC x CTQT 1439-004, citrandarin 'Indio' e limão-cravo 'Santa Cruz' estimulam o aumento da produção da laranjeira 'Valência'. LVK x LCR-038 e o citrandarin 'Indio' induzem o enxerto a produzir frutos de melhor qualidade.

Termos para indexação: *Citrus*, *Poncirus trifoliata*, qualidade do fruto, limoeiro cravo, Amazônia Ocidental, produção.

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Introduction

Research in modern citrus production has been directed to rootstocks that can lead to smaller scions (Forner-Giner et al., 2014), higher yield (Bowman et al., 2016b; Sau et al., 2018), better physical and chemical fruit quality (Sharma et al., 2016; Kirinus et al., 2019), resistance, or tolerance, to abiotic (Rodríguez-Gamir et al., 2010) and biotic problems (Shokrollah et al., 2011; Bowman et al., 2016a). The most efficient and sustainable method for controlling and preventing *Phytophthora* gummosis is the use of resistant, or tolerant, rootstocks which are compatible with the recommended scion varieties (Bassan et al., 2010).

In the state of Acre, in Brazil, the sweet orange [*Citrus sinensis* (L.) Osbeck] represents the third fruit tree for harvested area (575 ha in 2017), according to data from IBGE (2019). The state shows the necessary climatic conditions (humidity, temperature, luminosity, and precipitation) and soils for the cultivation of citrus, in addition to compensating prices for the fruits which have become an attractive activity for the region (Ledo et al., 2008).

The combination of sweet orange with Rangpur lime rootstock (*Citrus limonia* Osbeck) in the state of Acre is highlighted because this rootstock leads sweet orange trees to reach greater vigor and higher yield per plant, besides showing drought tolerance. However, this rootstock is highly susceptible to *Phytophthora* gummosis and, depending on the physical soil conditions, this microorganism can cause 100% plant death in the field, in a few years of cultivation. As Rangpur lime rootstock generates a high-canopy volume, the adopted spacing in the state of Acre reflects low-planting densities of the 'Valência' orange trees, which implies in a higher cost of production and lower profitability. Thus, when considering the current standard of scions for oranges, the Rangpur lime rootstock unfortunately does not comply with the requisites.

From studies with different rootstocks, Ledo et al. (1999) observed that 'Valência' orange showed the best agronomic characteristics when grafted onto Rangpur lime. Thus, despite its high susceptibility to *Phytophthora* gummosis and to other problems that the Rangpur lime confers onto the scion, this rootstock continued to be recommended for 'Valência' orange trees, keeping the narrow genetic diversity low and, consequently, increasing the risks of abiotic and biotic stresses, causing significant economic impacts, and threatening the entire production chain in the region (Carvalho et al., 2019). Therefore, due to the high susceptibility of the Rangpur lime, in addition to the other mentioned problems, the increase of diversification in the use of rootstocks has been suggested as necessary in Brazil (Fadel et al., 2018; Kirinus et al., 2019); in the state of Acre the proposition is not different.

In view of the mentioned problems in the state of Acre, and due to the lack of rootstocks which can be sustainable in citriculture in this region, it is extremely important to select new rootstocks, especially citrandarins, and some other hybrids. Citrandarins combine the qualities of mandarins, such as tolerance to citrus decline and sudden death, the qualities of citrus trifoliates, including immunity to citrus tristeza virus, and the resistance to citrus gummosis disease (Pompeu Junior & Blumer, 2014). Other citrus hybrids – from the Citrus Breeding Program of Embrapa Mandioca e Fruticultura – have been suggested as rootstocks, as they have been showing satisfactory results in other regions in Brazil.

As rootstock behaviors may vary according to the environment (Lado et al., 2018), the recommendations for superior genotypes should be based on local research.

The objective of this work was to select rootstocks, based on the agronomic characters and fruit quality of the 'Valência' orange tree.

Materials and Methods

The experiment was installed in January 2010, and evaluated from 2013 to 2017 in the municipality of Rio Branco (10°3'27.36"S, 67°39'58.50"W, at 176 m altitude), in the state of Acre, Brazil. The climate of the region is Aw (hot and humid), according to the Köppen-Geiger's classification, with a 30.9ºC maximum temperature, 20.8ºC minimum temperature, 1,648.94 mm annual precipitation, and 83% relative humidity. The soil of the experimental field is classified as red-yellow petroplinthic dystrophic (Santos et al., 2013), with a medium clayey texture. The characteristics of the soil, at 0–20 cm soil depths, were: 5.04 pH (H_2O); 3.45 $cmol_c$ dm^{-3} Ca; 1.46 $cmol_c$ dm^{-3} Mg; 0.22 $cmol_c$ dm^{-3} K; 0.01 $cmol_c$ dm^{-3} Na; 4.14 $cmol_c$ dm^{-3} H+Al; 0.03 $cmol_c$ dm^{-3} Al; 5.14 $cmol_c$ dm^{-3} sum of bases; and 5.17

$cmol_c$ dm^{-3} effective CEC; 2.07 mg dm^{-3} P; 8.23 g kg^{-1} C_{org}; 55.39% base saturation (V); 0.66% aluminum saturation; and 14.16 g kg^{-1} organic matter.

'Valência' sweet orange was budded onto each one of the nine rootstocks (treatments), as follows: 'Cleópatra' mandarin (*Citrus reshni* hort. ex Tanaka); TSKFL x CTTR-013, that is, 'Sunki Florida' [*Citrus sunki* (Hayata) hort. ex Tanaka] mandarin x 'Troyer' citrange [*C. sinensis* (L.) Osbeck x *Poncirus trifoliata* (L) Raf]; LVK x LCR-038, that is, 'Volkameriano' lime (*C. volkameriana* V. Ten. & Pasq.) x 'Cravo' lime (*C. limonia* Osbeck); TSKC x CTQT 1439-004, that is, 'Sunki' common mandarin x 'Thomasville' citrangequat [*Fortunella margarita* (Lour.) 'Swingle' x 'Willits' citrange]; LVK x LVA-009, that is, 'Volkameriano' lime x 'Valência' orange (*C. sinensis*); TSK x TRENG-256, that is, 'Indio' citrandarin{ 'Sunki' mandarin [*C. sunki* (Hayata) hort. ex Tanaka] x 'English' trifoliata [*P. trifoliata* (L.) Raf.] - 256 selection}; 'Santa Cruz' Rangpur lime (*C. limonia* Osbeck); TSKFL x CTC-25-002, that is, 'Sunki Florida' mandarin x C-25 citrange; TSKC x CTSW-038, that is, 'Sunki' common mandarin x 'Swingle' citrumelo (*C. paradisi* Macfad. x *P. trifoliata*).

The rootstocks were introduced, or obtained, by the citrus breeding program (Programa de Melhoramento Genético de Citros) of Embrapa Mandioca e Fruticultura, and they were previously selected for showing agronomic attributes of interest. A experimental design was carried out in randomized complete blocks, with nine treatments (rootstocks), three replicates, and two plants per plot, planted in 7 m x 7 m spacing without irrigation. The rootstocks were propagated from seeds, and the plants were T-budded in the nursery under 50% shading. The cultural practices were adopted in accordance with Mattos Junior et al. (2005).

The following variables were evaluated in 2017: plant height (H, m), measurement from the base of the trunk, close to the soil, up to the top of the plant, using a ruler; volume of the canopy (VC, m^3), which was based on the plant height (H) and on the diameter (D) (parallel and perpendicular to tree row), using the equation $V = 2/3 \times \pi \times Dm^2/4 \times H$; yield efficiency (YE, kg m^{-3}) determined through the relationship between yield (kg fruit per plant) and canopy volume (m^3), expressed in kg of fruit per m^3 of the canopy; scion/rootstock ratio (SRR), which was determined through the relationship between the trunk girth at 10 cm above and below the budding union for all trees; survival percentage (SP), calculated by the percentage of living trees until 2017; drought tolerance (DT), estimated during the critical period of drought occurring in September 2017, using a score scale based on visual symptoms of wilting leaves, ranging from grade 1 (no symptoms), grade 2 (slight wilting in up to half of the canopy), grade 3 (slight wilting throughout the canopy) up to grade 4 (intense wilting throughout the canopy and leaf drop), conducted by four evaluators (França et al., 2016).

Each year productivity was calculated considering the average production per plant and the planting density; after which, the average yield (AY, Mg ha^{-1}) of the five harvests (2013 to 2017) was calculated. The production per plant (kg per plant) of each harvest (2013 to 2017) was determined by the product of the average number of fruit per plant and average fruit mass, and then summed up to estimate the cumulative accumulated production of the five harvests (kg per plant).

The variables related to fruit quality were expressed in average of the harvests performed during the evaluation period (2013-2017). Ten fruit per plant were harvested each year, at the time of ripening, usually between July and August, for a total of 20 mature fruit per plot, and 60 per treatment; fruit were then transported to the post-harvest laboratory to evaluate the following parameters: mass (g); diameter (mm); length (mm); peel thickness (mm); juice yield (JY, %), calculated from the ratio [juice mass (g)/fruit mass (g)] × 100; total soluble solids (TSS), performed with a digital refractometer and expressed in °Brix; titratable acidity (TA), which was obtained by sample titration in 0.1 N NaOH, with the results expressed as percentage (%); TSS/TA (ratio); and technological index (TI), expressed in kilograms of TSS per box of 40.8 kg of fruit (kg SS box^{-1}) and calculated by the expression: $TI = [JY \times TSS \times 40.8] \times (10,000)^{-1}$.

Data were subjected to the analysis of variance, and means grouping was performed by the Scott-Knott's test at 5% probability, when significant differences were found between the treatments. For the variable production per plant, the experiment arranged in plots was subdivided by time, in which the plots were constituted by the years and the subplots by the rootstocks. The analysis of variance (F-test) was performed at 5% of probability, and the Scott-Knott's test ($p \leq 0.05$) was applied to the rootstock means, in cases of significant effect, and the Tukey's test for the year means. To calculate the survival percentage, all data were transformed into arcsin $(x/100)^{0.5}$.

Results and Discussion

'Cleópatra' mandarin, 'Indio' citrandarin, and 'Santa Cruz' Rangpur lime, and the hybrids TSKFL x CTTR-013 and LVK x LVA-009 induced a higher growth in 'Valência' oranges, for both height and canopy volume, thus indicating a greater vigor (Table 1).

'Cleópatra' and common 'Sunki' mandarins and 'Orlando' tangelo induced greater height and canopy volume of 'Valência' oranges evaluated at five and nine years after planting, in northern Paraná state, according to Auler et al. (2008), who state that the vigor of the scion variety is directly affected by the rootstock. After eleven years of evaluation, Chaparro-Zambrano et al. (2015) observed that the 'Cleópatra' mandarin was one of the rootstocks that induced a larger canopy volume of 'Valência' oranges, which was 43.71 m^3, that is a similar result to that of our study.

A size reduction was observed in plants grafted on TSKFL x CTC-25-002 and TSKC x CTSW-038 hybrids (Table 1). The adopted spacing for these rootstocks could be smaller, and the planting density consequently larger, with a probable increase of productivity. In addition, small-sized plants facilitate the applying of treatments to croppings and harvests (Portella et al., 2016).

The rootstocks which provided a greater yield efficiency to the scion were the hybrids TSKFL x CTTR-013, TSKFL x CTC 25-002, and TSKC x CTSW-038 (Table 1), reflecting the lower growth (height and canopy volume) in the case of the last two. The yield efficiency induced by the use of the rootstocks TSKC x CTQT 1439-004, LVK x LVA-009, and 'Cleópatra' mandarin was inversely proportional to plant growth (França et al., 2016). Forner-Giner et al. (2014) found that the low-vigor and high-yield efficiency provided by the rootstocks enable up to three times the increase of the planting density. In the same direction, Bacar et al. (2017) argue that rootstocks which induce high-yield efficiency and low-canopy volume are more interesting than those inducing high-canopy volume and higher-total yield of fruit per plant. The high-yield efficiency involving rootstocks may be related to the lower translocation of carbohydrates to the rootstock, in detriment of the greater availability of carbohydrates to the scion (Martínez-Alcántara et al., 2013).

The scion/rootstock ratio (SRR) was statistically similar in all treatments, although the most favorable rootstocks were the 'Cleópatra' mandarin, LVK x LCR-038, and the 'Santa Cruz' Rangpur lime (Table 1). Similar results were obtained for 'Valência Rhode Red' and 'Valência Late' (Yildiz et al., 2013). No symptoms

Table 1. Parameters of 'Valência' sweet orange (*Citrus sinensis*), grafted onto nine citrus rootstocks, measured in five harvests (2013-2017), in the conditions of Rio Branco, in the state of Acre, Brazil[(1)].

Rootstock	H (m)	VC (m^3)	YE (kg m^{-3})	SRR	SP (%)	DS	AY (Mg ha^{-1})
Cleópatra mandarin	3.67a	42.26a	1.69 c	0.90a	1.31* a (83)	2.62a	10.51a
TSKFL x CTTR-013	3.61a	39.93a	2.96a	0.75a	1.31* a (83)	2.79a	9.57a
LVK x LCR-038	3.43a	30.70b	2.67b	0.95a	1.31* a (83)	2.46a	10.56a
TSKC x CTQT-1439-004	3.76a	31.44b	1.57c	0.78a	1.57* a (100)	2.67a	7.99a
LVK x LVA-009	3.78a	39.39a	1.54c	0.87a	1.57* a (100)	2.13a	7.13a
Indio citrandarin	3.68a	39.67a	2.63b	0.86a	1.57* a (100)	2.08a	11.56a
Santa Cruz Rangpur lime	3.66a	42.21a	2.08b	0.97a	1.31* a (83)	2.09a	9.75a
TSKFL x CTC-25-002	2.87b	24.06c	3.01a	0.89a	1.31* a (83)	2.25a	8.30a
TSKC x CTSW-038	2.71b	25.09c	3.09a	0.89a	0.79* a (50)	2.17a	10.21a
Mean	3.46	34.97	2.04	0.85	90.74	2.20	9.73
Coefficient of variation (%)	8.67	16.74	11.83	9.54	32.04	16.03	19.91

[(1)]Means followed by equal letters do not differ by Scott-Knott's test, at 5% probability. H, plant height; VC, volume of the canopy; YE, yield efficiency; SRR, scion/rootstock ratio; SP, survival percentage; DS, dryness score in 2017; and AY, average yield. *Data were transformed into arcsin $(x/100)^{0.5}$. Data in parentheses: unprocessed.

associated with grafting incompatibility were observed during the evaluation period in the present study.

Plants grafted onto TSKC x CTQT 1439-004, LVK x LVA-009, and on the 'Indio' citrandarin showed 100% survival, differently from those grafted on the rootstocks 'Cleópatra' mandarin, TSKFL x CTTR-013, LVK x LCR-038, 'Santa Cruz' Rangpur lime, TSKFL x CTC-25-002, and TSKC x CTSW-038, which showed a stand reduction (Table 1), probably due to their seedling quality, as well as to poor soil drainage, crop management and, perhaps, to the presence of *Phytophthora* gummosis, since some plants showed cracks at the base of rootstock, yellowing, and subsequent death of the trees. Thus, the survival percentage would have been higher, if problems related to crop and soil management had been avoided.

There was no difference between rootstocks for drought tolerance (Table 1), although the plants have shown some deficiency symptoms, characterized by slight wilting from the top half up to the canopy. It is important to emphasize that the experiment was rainfed, which raises the hypothesis on the need of irrigation. These results are similar to those by França et al. (2016), who verified that the rootstocks did not show any influence in relation to the dry grades, after evaluating 'Valencia Tuxpan' grafted onto 14 rootstocks, in Rio Real, Bahia state, Brazil. According to Ramos et al. (2015), it is necessary to highlight the increasing importance of rational water consumption, which shows the need to develop drought-tolerant varieties, or to be more efficient in the use of available water. In this sense, Soares et al. (2015) state that genotypes which exhibit superior water-tolerance behavior should be included in breeding programs. With climate change, cultivators/farmers should be prepared for periods of high temperatures and high-soil water deficit, as these problems can significantly affect productivity.

The yield per plant varied over the years for all rootstocks, with emphasis for those grafted on LVK x LCR-038, TSKC x CTQT 1439-004, 'Indio' citrandarin, and 'Santa Cruz' Rangpur lime (Table 2).

The good performances of the rootstocks LVK x LCR-038, the 'Indio' citrandarin, and the 'Santa Cruz' Rangpur lime were also observed for 'Valência' sweet oranges under dry conditions in the Cerrado ecosystem, in the municipality of Colômbia, in the north of São Paulo state (Ramos et al., 2015). The rootstock influences the stability of production, production per plant, and accumulated production (Chaparro-Zambrano et al., 2015). The differences found in the literature for the same scion/rootstock combination, in different sites, are consistent, since climate, soil, and management practices influence the production and its variations.

The rootstocks that led the plants to reach a higher accumulated production per plant were the 'Santa Cruz' Rangpur lime, the 'Indio' citrandarin, and the LVK x

Table 2. Production of fruit per plant between 2013 and 2017, and accumulated production of 'Valência' sweet orange (*Citrus sinensis*) grafted onto nine rootstocks, in the edaphoclimatic conditions of Rio Branco, in the state of Acre, Brazil[(1)].

Rootstock	Production per plant (kg per plant)					Accumulated production (kg per plant)
	2013	2014	2015	2016	2017	
Cleópatra mandarin	6.39aC	25.81aB	29.46cB	49.35cB	73.28aA	184.29b
TSKFL x CTTR-013	4.35aD	32.68aC	43.74bCB	46.81bB	67.76bA	195.34b
LVK x LCR-038	5.43aC	31.78aB	54.52aB	75.13aA	77.60aA	244.46a
TSKC x CTQT 1439-004	7.25aD	27.58aC	44.25bB	51.77bB	80.31aA	211.16a
LVK x LVA-009	6.68aB	14.96bB	34.15cB	44.47cA	46.71cA	146.97c
Indio citrandarin	7.33aD	31.14aC	50.86aB	83.94aA	84.39aA	257.66a
Santa Cruz Rangpur lime	9.59aC	30.07aB	52.03aB	67.89aA	63.99bA	223.57a
TSKFL x CTC-25-002	4.59aD	13.65bC	22.93cC	49.57cB	67.77bA	158.51c
TSKC x CTSW-038	5.58aD	20.90aC	38.37bB	53.63bB	75.93aA	194.41b
Mean	6.354	25.39	41.14	58.06	70.86	201.82
Coefficient of variation (%)			16.74			9.60

[(1)]Means followed by equal uppercase letters in the rows, do not differ by Tukey's test, at 5% probability; and means followed by equal lowercases letters in the columns belong to the same group by Scott-Knott test's, at 5% probability.

LCR-038 and TSKC x CTQT-1439-004 hybrids, which exceeded 200 kg per plant in five harvests (Table 2). This production is higher than that reported by Fadel et al. (2018).

Plants grafted on 'Santa Cruz' Rangpur lime, on the 'Indio' citrandarin, and on the LVK x LCR-038, TSKC x CTQT-1439-004 hybrids, had higher height and canopy volume, which may explain the higher production, since these variables have a highly positive correlation (Fadel et al., 2018). On the contrary, smaller plants had smaller production, a fact which could be reversed with the increase of planting density, since they showed a greater yield efficiency.

The rootstocks TSKFL x CTTR-013, LVK x LCR-038, LVK x LVA-009, 'Indio' citrandarin, and 'Santa Cruz' Rangpur lime resulted in higher-fruit mass (Table 3). The use of the rootstocks LVK x LCR-038, 'Indio' citrandarin, and 'Santa Cruz' Rangpur lime resulted in 'Valência' fruit with greater mass, and higher-juice yield. Fruit size is an important parameter for producers and consumers (Hussain et al., 2013; Dubey & Sharma, 2016). According to Liu et al. (2015), citrus rootstocks have a significant effect on fruit size by regulating cell size and its interaction with growth regulators, water, and the plant root system itself.

The 'Valência' parameters of fruit diameter, length, and peel thickness were not altered by rootstocks (Table 3). This result is similar to that observed by França et al. (2016) for the 'Valência Tuxpan' orange. The peel thickness appears to be inversely associated with the juice yield, since the larger the peel thickness, the lower the juice percentage (Legua et al., 2011). 'Valência' orange grafted on all rootstocks met the requirements of the Brazilian fresh fruit market, and fit into the middle (65–71 mm) and high (>71 mm) diameter classes (Ceagesp, 2011).

The highest juice yields ranged from 53.8 to 64.94%, when the 'Cleópatra' mandarin and the 'Santa Cruz' Rangpur lime were used, respectively; however without differing from the 'Indio' citrandarin and the hybrids TSKC x CTQT-1439-004, and LVK x LCR-038 (Table 3). These values are higher than those obtained by Girardi et al. (2017) for 'Valência IAC', 'Valência Late Burjasot', 'Rhode Red Valência', 'Valência Temprana', 'Campbell Valência', and 'Dom João' fruit grafted on 'Sunki' mandarin and on 'Swingle' citrumelo rootstocks, as well as those obtained by França et al. (2016) for 'Valencia Tuxpan' grafted on 14 rootstocks, including the 'Cleópatra' mandarin, the 'Indio' citrandarin, and the 'Santa Cruz' Rangpur lime. The 'Santa Cruz' Rangpur lime and the 'Indio' citrandarin induced in the scion fruit juice yields between 64.94 and 63%, respectively, which are higher than those obtained by Castle et al. (2010) for 'Valência' orange tree grafted onto 12 rootstocks in Avon Park, Florida, USA.

Lado et al. (2018) indicated that fruit quality in citrus fruits is highly influenced by many environmental factors and production practices, and complex interrelationships can additionally exist among many

Table 3. Fruit traits of 'Valência' sweet orange tree (*Citrus sinensis*) grafted onto nine citrus rootstocks, in the edaphoclimatic conditions of Rio Branco, in the state of Acre, Brazil, in the period 2013-2017[1].

Rootstock	FM (g)	DIA (mm)	L (mm)	PT (mm)	JY (%)	TSS (°Brix)	TA (%)	Ratio	TI
Cleópatra mandarin	164.35b	72.24a	69.19a	3.25a	53.80a	8.71b	0.85b	10.03b	2.19b
TSKFL x CTTR-013	176.08a	72.77a	70.81a	3.13a	42.51b	8.63b	0.88b	10.42a	2.31b
LVK x LCR-038	179.27a	70.40a	72.31a	3.02a	58.89a	9.60a	0.83b	11.58a	2.98a
TSKC x CTQT-1439-004	166.88b	71.29a	67.69a	3.15a	54.80a	8.76b	0.99a	9.08c	1.97b
LVK x LVA-009	176.41a	69.32a	67.41a	3.38a	39.10b	8.57b	0.98a	9.92c	2.25b
Indio citrandarin	178.21a	71.50a	68.19a	3.17a	63.00a	9.75a	0.90b	11.26a	2.99a
Santa Cruz Rangpur lime	178.60a	73.80a	70.91a	3.35a	64.94a	9.84a	0.97a	10.09b	2.18b
TSKFL x CTC-25-002	150.67b	68.33a	69.75a	3.18a	47.80b	8.68b	0.88b	9.86c	2.19b
TSKC x CTSW-038	135.22b	67.82a	68.67a	3.29a	46.49b	8.54b	0.97a	9.28c	1.94b
Mean	169.85	71.83	71.32	3.41	52.37	8.22	0.91	10.16	2.33
Coefficient of variation (%)	10.12	2.75	2.16	10.15	8.13	2.33	4.44	5.88	15.05

[1]Means followed by equal letters do not differ by Scott-Knott's test, at 5% probability. Fruit traits: FM, fruit mass; DIA, diameter; L, length; PT, peel thickness; JY, juice yield; TSS, total soluble solids; TA, titratable acidity; TSS/TA, ratio; and TI, technological index.

of them to determine the final fruit quality. These authors believe that water relations, mineral nutrition, and hormonal contribution are factors which determine the influence of rootstocks on juice quality. Liu et al. (2015) suggested that differences for fruit quality may be associated with different levels of auxin and abscisic acid in fruits induced by rootstocks.

'Valência' fruit showed higher-TSS concentrations in combination with the rootstocks LVK x LCR-038, 'Indio' citrandarin, and 'Santa Cruz' Rangpur lime (Table 3). However, the values obtained are lower than the standards of 10 °Brix quality for table fruit (Ceagesp, 2011), which could be related to the high precipitation in the evaluated period, and to a dilution effect, or a decrease in the photosynthetic rate occurred in fruit. In addition, many cloudy days and low temperatures occurred due to the “cold fronts” coming from the South of Brazil, and entering in the state of Acre from the Pacific Ocean. Although Lado et al. (2018) assert that the TSS decrease may be associated with the increase of the percentage of extractable juice, it was not possible to detect this fact, except for the ‘Cleópatra’ mandarin and the TSKC x CTQT-1439-004 rootstocks.

Acidity is the main quality parameter perceived by consumers, and oranges have above 0.5% citric acid contents for industry, when they are ripe, or above 0.75% for in natura consumption. Thus, all the rootstocks were within the recommended standards, especially the hybrids TSKC x CTQT-1439-004, LVK x LVA-009, and TSKC x CTSW-038, and the 'Santa Cruz' Rangpur lime, with the highest citric acid percentages (Table 3). Auler et al. (2008) did not detect differences for acidity after evaluating the behavior of 'Valência' orange trees grafted on six rootstocks in Paraná state, Brazil.

The ratio is an important variable used to estimate the ripeness of fruits (Legua et al., 2011). The TSKFL x CTTR-013 and LVK x LCR-038 hybrids, and the 'Indio' citrandarin showed a higher ratio, surpassing the 'Santa Cruz' Rangpur lime and the 'Cleópatra' mandarin, which obtained an intermediate ratio (Table 3). The ratio values ranged from 9.08 to 11.58, and were lower than those found by Auler et al. (2008).

Papadakis et al. (2008) determined the averages of 10.7 for 'Valência Lue Gim Gong' orange trees and 9.8 for 'Valência Campbell' orange tree which contained high-quality edible fruit. According to classification standards for table citrus fruit, the 'Valência' orange must have at least 44% juice, and a 9.5 ratio (Ceagesp, 2011).

The rootstocks which induced the highest-technological index values were 2.98 and 2.99 for the LVK x LCR-038 hybrid and the 'Indio' citrandarin, respectively (Table 3). These results are higher than those found by Girardi et al. (2017) for all evaluated scions, including 'Valência', which were grafted on 'Swingle' citrumelo and 'Sunki' mandarin.

The 'Cleópatra' x *P. trifoliata* 'Rubidoux', 'C-13' citrange, and 'Sunki' x *P. trifoliata* 'Benecke' hybrids induced 2.70, 2.48, and 2.44, respectively, which are the highest-technological indexes (TI) in 'Valência' orange tree (Fadel et al., 2018). The TIs between 1.49 and 2.53 for 'Valência Tuxpan' orange tree determined respectively onto LVK LVA-009 and 'Riverside' citrandarin was determined by França et al. (2016); these values did not differ from that determine in 'Indio' citrandarin of 2.05, in the present work.

These results have enabled to identify promising rootstocks to compose the citrus production system in the state of Acre, Brazil. Therefore, the 'Valência' orange production follows the precepts of modern citrus cultivation. As perspectives, it is expected that the selected rootstocks will be used by the region’s producers and by nursery farmers for seedling production. These genotypes will be able to compose assays with different scion varieties in the Amazon biome.

Conclusions

1. The rootstocks affect the agronomic characters and fruit quality of 'Valência' orange tree (*Citrus sinensis*).
2. 'Valência' shows a lower height and lower canopy volume, as well as a higher-yield efficiency when grafted onto TSKC x CTSW-038 than on the other rootstocks, which may allow of a higher-planting density.
3. The rootstocks LVK x LCR-038, TSKC x CTQT 1439-004, 'Indio' citrandarin, and 'Santa Cruz' Rangpur lime promote the productivity increase of 'Valência' orange.
4. LVK x LCR-038 and 'Indio' citrandarin rootstocks induce 'Valência' orange to yield better quality fruit.

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