

Agronomic performance of the 'Pera' orange grafted onto nine rootstocks under the conditions of Rio Branco, Acre, Brazil

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ABSTRACT: Brazil is the world's largest sweet orange producer, but production in the state of Acre is small and does not meet the local demand, despite having climatic conditions that are adequate for its cultivation. The objective of this study was to evaluate the behavior of the 'Pera' orange using different rootstocks under the edaphoclimatic conditions of Rio Branco, Acre, Brazil. We grafted the scion of the 'Pera' orange onto nine citrus rootstocks: 'Cleopatra' mandarin, TSKFL x CTTR – 013, LVK x LCR – 038, TSKC x CTQT 1439 – 004, LVK x LVA – 009, 'Indio' citrandarin, 'Santa Cruz Rangpur' lime, TSKFL x CTC - 25 – 002, and TSKC x CTSW – 038. The experiment was organized in a random block design with three replicates and two plants per parcel. The following characteristics were evaluated: compatibility between scion and rootstocks, tolerance to drought, production and fruit quality. There was an effect of the rootstocks on the behavior of the 'Pera' variety. The 'Santa Cruz Rangpur' lime, 'Indio' citrandarin, and the hybrid LVK x LCR - 038 rootstocks presented the best performance of the 'Pera' orange. Therefore, they constitute an alternative to the 'Rangpur' lime and may be incorporated into the current 'Pera' orange production system of the region.

Key words: *Citrus* spp.; fruit quality; production; Western Amazon

Desempenho agrônômico de laranja 'Pera' enxertada em nove porta-enxertos nas condições de Rio Branco, Acre

RESUMO: O Brasil é o maior produtor mundial de laranja-doce, mas no Estado do Acre a produção é pequena e não atende à demanda local, apesar de possuir condições climáticas adequadas ao seu cultivo. O objetivo do trabalho foi avaliar o comportamento de laranja 'Pera' sobre diferentes porta-enxertos nas condições edafoclimáticas de Rio Branco, Acre. A copa de laranja 'Pera' foi enxertada em nove porta-enxertos de citos: 'Cleópatra', TSKFL x CTTR – 013, LVK x LCR – 038, TSKC x CTQT 1439 – 004, LVK x LVA – 009, Citrandarin 'Indio', 'Santa Cruz Rangpur' lime, TSKFL x CTC - 25 – 002 e TSKC x CTSW – 038. Empregou-se um delineamento em blocos ao acaso com três repetições e duas plantas na parcela. Foram avaliadas características vegetativas, compatibilidade entre copa e porta-enxertos, tolerância à seca, produção e qualidade dos frutos. Houve efeito dos porta-enxertos sobre o comportamento da variedade copa. Os porta-enxertos limoeiro 'Cravo Santa Cruz', citrandarin 'Indio' e o híbrido LVK x LCR – 038 refletiram em melhor desempenho da laranja 'Pera'. Sendo assim, constituem como alternativas ao limoeiro 'Cravo' e podem ser incorporados ao atual sistema de produção de laranja da região.

Palavras-chave: *Citrus* spp.; qualidade de frutos; produção; Amazônia Ocidental

Introduction

Brazil is the largest world producer of sweet oranges [*Citrus sinensis* (L). Osbeck]. The state of Acre has immense potential for producing oranges due to the market demand, given that a significant part of what is consumed there comes from other regions, especially from Southeast Brazil. Other aspects worth emphasizing are the edaphoclimatic aptitude for cultivating this species and the need to honor environmental sustainability guided by the necessity to reduce the pressure regarding deforestation. The state has over two million deforested hectares, and citrus activity could occupy part of this area (INPE, 2018).

Despite the potential, the average yield (15.2 t ha⁻¹) of Acre State is well below the national average (26.2 t ha⁻¹), and furthermore the largest average in Brazil is achieved by the state of Sao Paulo (31.9 t ha⁻¹). Acre State occupies the 22nd position in the national ranking with 579 ha of planted orange trees in 2016 (IBGE, 2018).

Inadequate management practices for growing oranges such as the use of inappropriate rootstocks may partly explain the low production of the orchards, seeing that the rootstock choice is one of the most critical aspects in planting management as scion cultivars respond differently for growth, fruit quality, and nutrient accumulation according to the rootstock used (Dubey & Sharma, 2016). It is widely recognized as one of the most important components of a healthy and productive citric tree (Bowman & Faulkner, 2016).

There is a predominance of the 'Rangpur' lime rootstock in the Acre region for conferring greater vigor to the scion and for being easy to manipulate in nurseries for producing seedlings. However, it is susceptible to *Phytophthora* spp. gomosis, being the most significant disease of Acre's citriculture due to its high incidence and severity which results in the premature death of the plants in the field. Thus, citrus production is highly vulnerable due to the low genetic diversity and the use of a single rootstock.

Therefore, there is a need to introduce new rootstock varieties to diversify the genetic basis and provide more options to producers. Having both advantages and disadvantages, no rootstock is unique nor can be considered ideal for all citrus species, all the varieties within a species, and especially all types of agroclimatic regions (Sau et al., 2018).

The Citrus Breeding Program of Embrapa Cassava & Tropical Fruits has been conducting controlled hybridization studies since September 1988, with the objective to produce new varieties, notably of rootstocks, adapted to the different Brazilian geographical regions and which may be tolerant to drought and resistant to *Phytophthora* gomosis and the Citrus tristeza virus (CTV) (Santana et al., 2018).

In this context, the objective of this study was to evaluate the agronomic performance of the 'Pera' orange grafted onto nine rootstocks under the edaphoclimatic conditions of Rio Branco, Acre, Brazil, so as to provide alternatives to the 'Rangpur' lime rootstock.

Material and Methods

The experiment was installed and conducted in the municipality of Rio Branco, AC, Brazil, located at latitude 10° 3' 27.36" S and longitude 67° 39' 58.50" W, at an altitude of 176 m, in an area of plain terrain tending towards soft wavy, and whose soil was classified as petroplinthic Dystrophic Yellow-Red Argisol of medium clay texture, with its characterization in the 0-20 layer presented in Table 1.

The experiment was implanted in 2010 and evaluated from 2013 to 2017. The climate of the region is AW (warm and humid) according to the Köppen classification, with a maximum temperature of 30.9 °C, minimum temperature of 20.8 °C, annual precipitation of 1,648.94 mm, and relative humidity of 83% (Agritempo, 2018). Figure 1 presents the meteorological conditions during the evaluation period.

The scion of the 'Pera' orange grafted onto nine citrus rootstocks was evaluated (Table 2).

A complete randomized block design with nine treatments represented by the rootstocks were employed with three replicates. Each constituted of two plants spaced 7.0 m between lines and 7.0 m between plants in a density of 204 plants per hectare.

The planting was realized in holes with dimensions of 0.40 x 0.40 x 0.40 m through seedlings produced by a grafting method in a nursery with 50% shading. The cultural treatments used for the culture in the execution period of the experiment included soil correction before planting and fertilization at the beginning and end of the rainy season (November and May)

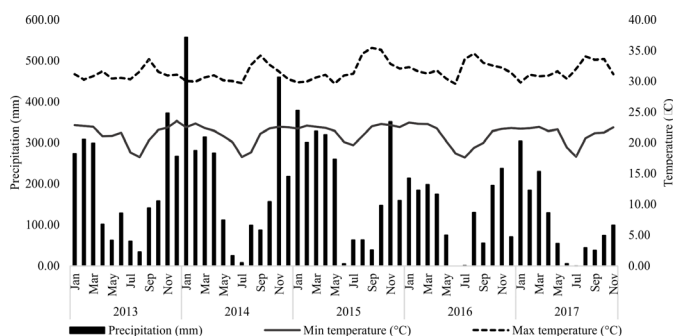


Figure 1. Pluviometric precipitation, maximum and minimum monthly air temperature from 2013 to 2017 in the experimental area. Rio Branco, AC, Brazil.

Table 1. Soil characterization of the experimental area in which the 'Pera' orange was evaluated in combination with nine rootstocks. Rio Branco, AC, Brazil.

pH (H ₂ O)	Ca	Mg	K	H + Al	Al	P	C _{org} ^I	M.O ^{II}	SB ^{III}	CTC ^{IV}	V ^V	Al ^{VI}
	(cmol _c dm ⁻³)					(mg dm ⁻³)	(g kg ⁻¹)		(cmol _c dm ⁻³)		(%)	
5.04	3.45	1.46	0.22	4.14	0.03	2.07	8.23	14.16	5.14	5.17	55.39	0.66

I - Organic carbon; II: organic matter; III: sum of bases; IV: cation exchange capability; V: saturation of bases; VI: saturation by aluminum.

Table 2. Identification and characteristics of citrus rootstocks introduced or obtained by the Citrus Breeding Program of Embrapa Cassava & Tropical Fruits (PMG Citros) and evaluated in combination with the 'Pera' orange under the conditions of Rio Branco, Acre, Brazil.

Abbreviation / Common name	Parental or species	Potential identified in other regions**
CLEO ('Cleopatra' mandarin)	<i>Citrus reshni</i> hort. ex Tanaka	Induced high vigor to the scion. Tolerant of CVT, exocortis, xiloporosis, decline, and sudden death. Tolerance to cold and to alkaline soils. Average resistance to gomosis. Induces high productivity and late production start. Good tolerance to drought.
TSKFL x CTRR - 013	TSKFL: 'Sunki of Florida' mandarin [<i>C. sunki</i> (Hayata) hort. ex Tanaka]; CTRR: 'Troyer' Citrange [<i>C. sinensis</i> x <i>Poncirus trifoliata</i> (L.) Raf.]	Frank trees selected in Bahia for their tolerance to drought and CTV.
LVK x LCR - 038	LVK: 'Volkamer' lemon (<i>C. volkameriana</i> Ten. & Pasq.); LCR: 'Rangpur' lime (<i>C. limonia</i> Osbeck)	Induced scion reduction and high productivity, with an early start of good quality fruit production. Moderate susceptibility to <i>Phytophthora</i> spp. gomosis. Tolerant of CTV and drought.
TSKC x CTQT 1439 - 004	TSKC: common 'Sunki' mandarin; CTQT: 'Thomasville' citrangequat [<i>Fortunella margarita</i> (Lour.) Swingle x citrange 'Willits']	Did not stand out with the scion of a Valencia orange in São Paulo. Tolerant of CTV.
LVK x LVA - 009	LVK: 'Volkamer' lemon (<i>C. volkameriana</i> Ten. & Pasq.); LVA: 'Valência' sweet orange	Induced good productivity to the Okitsu satsumain RS, but did not present good performance in SP and BA when grafted on the Valencia orange. Intolerant of CTV.
TSK x TRENG - 256 ('Indio' itrandarin)	TSK: 'Sunki' Mandarin [<i>C. sunki</i> (Hayata) hort. ex Tanaka]; TRENG 256: Trifoliata [<i>Poncirus trifoliata</i> (L.) Raf.] 'English' selection	Induced high vigor to the scion and high productivity, with an early start of good quality fruit production. Tolerant of decline and CTV. Resistant to gomosis. Good tolerance to drought.
LCRSTC ('Santa Cruz Rangpur' lime)	<i>C. limonia</i> Osbeck	Induced average vigor to the scion. Induced high productivity and an early good quality fruit production. Susceptible to <i>Phytophthora</i> spp. gomosis, MSC, and exocortis, tolerant of CTV and drought.
TSKFL x CTC-25 - 002	TSKFL: 'Sunki of Florida' mandarin [<i>C. sunki</i> (Hayata) hort. ex Tanaka]; CTC-25: citrange C25	Frank trees selected in Bahia for their tolerance to drought.
TSKC x CTSW - 038	TSKC: common 'Sunki' mandarin; CTSW: citrumelo 'Swingle' (<i>C. paradise</i> Macfad. x <i>P. trifoliata</i>)	Induced a size reduction of the scion variety, high production, precocity, and good fruit quality, tolerance to drought, little susceptible to gomosis, and tolerant of CTV.

** Rodrigues et al. (2014); Ramos et al. (2015); Rodrigues et al. (2015) and Schuch et al. (2017).

following the culture recommendations. The experiment was not irrigated, and we did not perform phytosanitary controls.

We measured the following characteristics in the last year of evaluation (2017):

- plant height H (m), measured from the ground to the top;
- canopy volume V (m³) = ((2/3π)xDm²/4) x H, where: π = 3.14; Dm (m) = (DI+Ds)/2, with DI (m) being obtained from the measure of the scion in the line direction and Ds (m) in the direction perpendicular to the street; H = plant height (m);
- productive efficiency, calculated from the ratio between the production per plant and the canopy volume (kg m⁻³);
- compatibility through the ratio between the diameters of the rootstock trunk and the graft with the aid of a bevel gauge, both measured 10 cm above and below the grafting point;
- survival percentage (%) calculated by the ratio of dead plants to those living up to 2017;
- tolerance to field drought 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).

From 2013 to 2017, the plant yield (kg ha⁻¹) was evaluated by multiplying the average number of fruits per plant and the average fruit mass (g), as well as the cumulative production (kg pl⁻¹) computed by the production sum in the five harvests.

Average productivity was calculated through multiplying the average production per plant (kg pl⁻¹) in the five harvests by the number of plants per hectare (planting density).

The harvests were carried out in August, with only one collection per harvest. We harvested ten fruits per plant, sending them to the Post-Harvest laboratory of Embrapa Acre. The fruit quality variables were expressed in average terms of the harvests from 2013 to 2017, in which we evaluated:

- average fruit mass (g), by weighing on a digital scale;
- fruit diameter (mm) and length (mm), measured with a digital pachymeter;
- fruit peel thickness (mm), measured with a digital pachymeter;
- juice yield JY (%), calculated from the ratio between the masses of juice and fruit, multiplied by 100;

- total soluble solids (TSS), estimated with a digital refractometer (°Brix);
- titratable acidity (TA), obtained by the titration method with 0.1 N NaOH, in which we weighed approximately 1.0 g of juice, added distilled water until completing 50 mL, and three drops of the phenolphthalein 1% indicator. After agitation, we titrated the solution with 0.1 N NaOH until the color changed to slightly pinkish. The percentage of citric acid in the juice was calculated from the amount of NaOH used;
- ratio between TSS and TA; and
- technological index (TI), expressed in kg of total soluble solids per box ($\text{kg.SS}\cdot\text{box}^{-1}$) and calculated by the expression $\text{TI} = [\text{JY} \times \text{SS} \times 40.8] \times 10.000^{-1}$, where TI is the technological index expressed in kilograms of soluble solids per box, JY is the juice yield, TSS is the soluble solids content, and 40.8 kg is the standard mass of the harvest box (Di Giorgi et al., 1990).

The effects of treatments (rootstocks) were evaluated through analysis of variance and the means compared by Scott-Knott test ($p < 0.05$). An arrangement in a split-plot scheme over time was considered for comparing the production per plant in the five harvests (2013-2017). The plots were constituted by harvests and the split-plots by the rootstocks. The Tukey test was applied at 5% significance for analyzing the plots (harvests), while the Scott-Knott test at 5% probability was implemented for analyzing the split-plots (rootstocks). We performed an analysis of variance in the case of significant interactions ($p < 0.05$), verifying the effect of the rootstocks within the harvest and vice-versa.

Results and Discussion

The 'Cleopatra' mandarin, LVK x LVA - 009, 'Santa Cruz Rangpur' lime and 'Indio' citrandarin induced the most significant growth in height and canopy volume in the plants. On the other hand, TSKFL x CTTR-013, TSKFL x CTC - 25 - 002, and TSKC x CTSW 039 yielded plants with smaller sizes and canopy volumes (Table 3).

The growth characteristics of citrus plants being influenced by the rootstocks must be considered upon defining the spaces

between plants and lines of the orchard (Yildiz et al., 2013), so as to provide as many trees as possible per area without affecting productivity and fruit quality. According to Portela et al. (2016), small plants present advantages such as the ease of executing cultural treatments like phytosanitary control, fruit harvesting, and pruning, as well as enabling higher planting densities.

Hybrid rootstocks TSKFL x CTTR - 013 and TSKFL x CTC - 25 - 002 yielded the most significant productive efficiency of the 'Pera' orange due to the greater number of fruits (kg) per canopy volume (m^3) (Table 3). The results were inversely proportional to the growth of the plant in height and canopy volume, constituting a finding similar to that of França et al. (2016) for the 'Valencia Tuxpan' orange grafted onto different rootstocks. Low vigor associated with high productive efficiency is an indicator that the density can reach up to the triple of what is generally adopted (Forner-Giner et al., 2014).

Three groups were formed regarding compatibility: it was high when the 'Pera' orange was combined with the 'Cleopatra' mandarin, LVK x LCR - 039 and 'Santa Cruz Rangpur' lime; average when combined with the TSKC x CTQT 1439 - 004, LVK x LVA - 009, 'Indio' citrandarin, and TSKFL x CTC - 25 - 002; and low when grafted onto the TSKFL x CTTR - 013 and TSKC x CTSW - 038 (Table 3), with the latter case being indicative that such rootstocks are incompatible with the 'Pera' orange.

Compatibility between scion and rootstock is a requirement to be considered and is as vital as the agronomic attributes and the resistance to biotic and abiotic stresses (Emmanouilidou & Kyriacou, 2017). These authors found that the scion of Lane Late orange (0.493) and Delta (0.581) orange grafted onto Citrumelo presented very low compatibility indices of 0.49 and 0.58, respectively, as well as the presence of anomalies in the grafting area and the consequent decline of the plants.

There was a 100% survival of the 'Pera' orange plants over the 'Cleopatra' mandarin, LVK x LVA-009, 'Indio' citrandarin, and TSKFL x CTC-25 - 002 rootstocks (Table 2). Nevertheless, a reduction occurred for the combinations with TSKFL x CTTR - 013, LVK x LCR - 038, TSKC x CTQT 1439 - 002, 'Santa Cruz Rangpur' lime, and TSKC x CTSW - 039, caused by *Phytophthora* gomosis.

Table 3. Plant height (HGT), canopy volume (CVOL), productive efficiency (PE), compatibility (COM), survival percentage (SP), and tolerance to drought (TD) in 2017 of the 'Pera' orange [*Citrus sinensis* (L.) Osbeck]] grafted onto nine rootstocks under the conditions of Rio Branco, Acre, Brazil.

*Rootstocks	HGT (m)	CVOL (m^3)	PE (kg m^{-3})	COM	SP (%)	TD
'Cleopatra' mandarin	3.64a	41.06a	1.93b	0.95a	100.00a	2.46a
TSKFL x CTTR - 013	2.71b	25.02c	2.95a	0.54c	66.66b	2.54a
LVK x LCR - 038	3.35a	35.96b	1.98b	0.91a	66.66b	1.83a
TSKC x CTQT 1439 - 004	3.28a	32.02b	2.09b	0.70b	83.33b	2.37a
LVK x LVA - 009	3.23a	41.48a	2.00b	0.77b	100.00a	2.33a
'Indio' Citrandarin	3.51a	40.99a	1.97b	0.82b	100.00a	2.54a
'Santa Cruz Rangpur' lime	3.37a	41.49a	2.33b	0.96a	83.33b	2.21a
TSKFL x CTC - 25 - 002	2.75b	26.36c	3.25a	0.71b	100.00a	2.50a
TSKC x CTSW - 038	2.78b	24.55c	3.12a	0.43c	83.33b	2.16a
Mean	3.41	31.99	2.20	0.75	87.03	2.22
CV (%)	9.13	13.27	11.15	6.49	13.03	12.37

Mean values followed by the same letter do not differ from each other according to the Scott-Knott test at 5% probability.

Although the rootstocks did not differ regarding tolerance to drought (Table 3), the results indicate that the plants were sensitive to the adverse conditions of the region. Precipitation was low in September 2017 (the period in which we performed the drought evaluation), around 36 mm, which incidentally happened the day after we assessed the plants, temperatures were high, and relative humidity was low (Figure 1). This indicates there is a tendency for using irrigation in more technologically advanced systems, especially when using rootstocks which are less vigorous or naturally more susceptible to drought despite being resistant to gomosis, and which result in more productive scions and plantings. Water deficiency may significantly affect productivity and fruit quality (Fadel et al., 2018); therefore, cultivators must be prepared for the climatic changes that are occurring in the region, as well be aware of the importance of implementing new technologies for citrus planting.

We observed differences among the rootstocks in each of the harvests and among the evaluation years (Table 4).

It may be deduced that production began to stabilize from the moment it becomes the same between harvests, not differing in statistical terms, and as long as there is no production alternation, management alteration, natural development or growth in the plants, or environmental conditions that may affect production. In this context, TSKFL x CTTR - 013, LVK x LCR - 038, LVK x LVA-009, 'Indio' citrandarin, and TSKFL x CTC-25 - 002 started to stabilize production from the fourth year. From the practical viewpoint, depending on the scion, the rootstock, and the environmental conditions, this information is quite interesting as it may indicate for how long an experiment must be conducted to recommend varieties.

In terms of precocity, which is determined by the quotient between summing the production in the first three years and the cumulative production of the evaluated period (Cantuarias-Avilés et al., 2011), we found the following decreasing order: 'Santa Cruz Rangpur' lime(36.6%) > TSKC x CTSW - 038 (36.2%) > LVK x LCR - 038 (33.5%) > TSKFL x CTTR - 013 (32.3%) > 'Cleopatra' mandarin (31.3%) > TSKC x

CTQT 1439 - 004 (30.8 %) > 'Indio' citrandarin (30.3%) > TSKFL x CTC-25 - 002 (30.3%) > LVK x LVA-009 (28.5%). Pompeu Junior & Blumer (2014) found that the 'Pera' orange was more precocious when combined with citrandarins Cleopatra x Rubidoux (1660) and Sunki x Benecke (1697), which yielded 44% and 42% of the total production in the first three harvests, respectively, followed by the 'Rangpur' lime (41%). The lowest precocity was found with 'Rangpur' lime x Swingle citromonia (30%) and C-13 citrange (25%) rootstocks.

The largest cumulative production in the period from 2013 to 2017 was observed for the combinations of the 'Pera' orange with LVK x LCR 038, 'Indio' citrandarin, and 'Santa Cruz Rangpur' lime (Table 4). The 'Pera-Rio' orange combined with the two latter rootstocks under the edaphoclimatic conditions in the state of Amazonas showed to be more productive (Santos, 2015). Sampaio et al. (2016) detected a similar result under the dry conditions in the state of Bahia.

Schinor et al. (2013) detected that the largest production of the 'Pera' orange grafted onto different hybrids of the 'Sunki' x *Poncirus trifoliata* was related to the higher canopy volume; a fact not wholly proven in this study.

Regarding average productivity, there were no differences among the scion/rootstock combinations (Table 3), and productivity was low all around due to the small values obtained in the first production years, and especially to the low planting density adopted (204 plants per hectare).

The fruit diameters and lengths, as well as the technological indices, were not altered by the rootstocks. In contrast, we found that the rootstocks influenced the fruit mass, peel thickness, juice yield, total soluble solids content, titratable acidity, and ratio (Table 5).

Three groups were formed regarding fruit mass, with LVK x LCR - 038, 'Indio' citrandarin, and 'Santa Cruz Rangpur' lime conferring the highest values; while 'Cleopatra' mandarin, TSKFL x CTTR - 013, TSKC x CTQT 1439 - 004, and TSKC x CTSW - 038 conferred intermediate values; and LVK x LVA-009 and TSKC x CTSW - 039 the smallest values (Table 4). Regardless of the group, the results of this study are inferior to those determined by Simonetti et al. (2015), who detected

Table 4. Yield per plant from 2013 to 2017, cumulative production and average productivity (PROM) of the 'Pera' orange [*C. sinensis* (L.) Osbeck] grafted onto nine rootstocks under the conditions of Rio Branco, Acre, Brazil.

Rootstocks	Yield per plant (kg pl ⁻¹)					Cumulative production (kg pl ⁻¹)	PROM (t ha ⁻¹)
	2013	2014	2015	2016	2017		
'Cleopatra' mandarin	3.11bD	14.81aC	28.98bCB	38.15cB	64.93aA	149.98b	6.19a
TSKFL x CTTR - 013	6.41aC	13.64aC	30.27bB	47.24bA	58.03bA	155.59b	6.35a
LVK x LCR - 038	6.09aC	13.42aC	40.89aB	58.09aA	61.69aA	180.19a	7.35a
TSKC x CTQT 1439 - 004	8.32aD	10.11bD	28.15bC	42.74cB	61.68aA	151.01b	6.16a
LVK x LVA-009	3.77bC	13.44 aCB	27.26bB	56.45aA	55.04bA	155.96b	6.36a
'Indio' Citrandarin	4.50bC	13.84aC	37.01aB	57.75aAB	69.72aA	182.82a	7.46a
'Santa Cruz Rangpur' lime	6.47aC	15.78aC	47.44aB	56.35aB	64.56aA	190.60a	7.77a
TSKFL x CTC-25 - 002	2.20bC	12.20bC	32.61bB	48.06bA	60.32aA	155.40b	6.34a
TSKC x CTSW - 038	6.64aC	9.74bC	41.50cB	44.06cB	57.79bA	159.73b	6.51a
Mean	5.28	13.00	34.90	49.88	61.53	164.59	6.72
CV (%)			16.76			7.86	23.12

Mean values followed by the same uppercase letter in the line do not differ from each other according to the Tukey test, and lowercase letters in the column belong to the same group according to the Scott-Knot test at 5% probability.

Table 5. Mean mass (FM), diameter (DIA), length (LEN), peel thickness (PTHK), juice yield (JY), total soluble solids (TSS), titratable acidity (TA), ratio, and technological index (TI) of the fruits of 'Pera' orange [*Citrus sinensis* (L.) Osbeck] grafted onto nine rootstocks under the conditions of Rio Branco, Acre, Brazil, from 2013 to 2017.

Rootstocks	FM (g)	DIA	LEN (mm)	PTHK	JY (%)	TSS (°Brix)	TA (% citric acid)	RATIO	TI* (kg.SS.box ⁻¹)
'Cleopatra' mandarin	164.02b	69.41a	69.84a	3.35b	51.14a	8.71 b	0.86a	8.19a	1.43a
TSKFL x CTTR - 013	163.00b	65.67a	64.24a	3.77 a	46.95b	9.20 ^a	0.75b	8.75a	1.45a
LVK x LCR - 038	170.19a	66.16a	70.53a	3.37b	51.82a	9.40 a	0.72b	8.35a	1.46a
TSKC x CTQT 1439 - 004	164.95b	61.26a	70.47a	3.87a	45.41b	8.39 b	0.89a	7.49b	1.32a
LVK x LVA -009	135.35c	69.42a	71.97a	3.95a	46.16b	8.77 b	0.71b	7.45b	1.31a
'Indio' citrandarin	172.93a	69.16a	68.86a	4.08a	51.45a	9.55 a	0.87a	8.60a	1.55a
'Santa Cruz Rangpur' lime	178.70a	67.02a	71.52a	3.38b	53.52a	9.34 a	0.86a	8.53a	1.66 a
TSKFL x CTC-25 - 002	151.26c	59.28a	65.53a	4.11a	45.31b	8.88 b	0.73b	7.29b	1.33a
TSKC x CTSW - 038	159.35b	65.03a	64.54a	3.89a	40.41b	8.84 b	0.85a	7.44b	1.40a
Mean	162.19	64.49	68.61	3.77	48.02	8.96	0.80	7.99	1.43
CV (%)	10.04	8.53	6.42	10.87	6.29	4.46	3.62	6.56	5.76

Mean values followed by the same letter do not differ from each other according to the Scott-Knott test at 5% probability.

a positive correlation among this characteristic, plant height, and canopy volume of the 'Pera' orange. The rootstocks with the highest heights and canopy volumes were also those that led the scion to have larger fruit masses.

For table consumption, it is preferable to have fruits with thinner peels since peeling is easier and a greater edible portion of the fruit is available (Sau et al., 2018). Therefore, the 'Cleopatra' mandarin, LVK x LCR - 038 and the 'Santa Cruz Rangpur' lime stood out for presenting fruits with thinner peels (Table 4). These rootstocks also stood out because of the juice yield, which indicates the two variables are inversely related, i.e. the smaller thickness of the peel reflects a higher juice yield. Continella et al. (2018) did not detect differences in the thickness of the 'Tarocco Scirè' orange peel.

According to Hussain et al. (2013), the fresh or industrial fruit market is determined by fruit size. Average-sized to large fruits are preferable for *in natura* consumption. Small fruits are primarily destined to the juice industry. Regarding the fruit diameters of the 'Pera' orange, the size was predominantly medium (between 65 and 71mm), according to the citrus classification norms (CEAGESP, 2011).

The 'Pera' orange fruit combined with the 'Cleopatra' mandarin, LVK x LCR - 038, 'Indio' citrandarin, and 'Santa Cruz Rangpur' lime rootstocks presented higher juice yields, above 51% (Table 5). Schinor et al. (2013) found that the 'Pera' orange presented values between 42 and 56% depending on the rootstock used, and that the majority of the scion/rootstock combinations presented a juice yield below 51%.

The hybrid TSKFL x CTTR - 013 and LVK x LCR - 038 rootstocks, as well as the 'Indio' citrandarin and 'Santa Cruz Rangpur' lime, conferred the highest total soluble solids contents to the 'Pera' orange (Table 5). The 'Indio' citrandarin combined with the 'Pera' orange stood out regarding soluble solids content (Sampaio et al., 2016). The averages for this variable obtained in this study are lower than those established by the citrus classification norms, which is of 10 °Brix for table fruit (CEAGESP, 2011). Such results may be attributed to the climatic conditions, especially the high precipitations that occurred in the fruit formation phase (Figure 1). There exists a hypothesis that a higher juice yield results in a lower soluble

solid content (Lado et al., 2018), but such an assumption was only valid for the combination of 'Pera' orange and 'Cleopatra' mandarin, leading to the deduction that such a hypothesis depends on the rootstock, the environmental conditions, and the interaction between these two factors.

We observed fruits with higher acidity in plants grafted over the 'Cleopatra' mandarin, TSKC x CTQT 1439 - 004, 'Indio' citrandarin, 'Santa Cruz Rangpur' lime, and TSKC x CTSW - 038 (Table 5). Temperature is the factor which most influences the accumulation of citric acid, which decreases after reaching the maximum value due to the increase in fruit size and its utilization in the temperature-dependent respiratory process (Simonetti et al., 2015). High temperatures in the maturation phase generally result in less acidic fruits, a fact also observed in this study (Figure 1).

The 'Cleopatra' mandarin, TSKFL x CTTR - 013, LVK x LCR - 038, 'Indio' citrandarin, and 'Santa Cruz Rangpur' lime induced the formation of fruits with larger ratios. This variable is considered one of the most important in citrus and an indicator that helps determine the fruit maturation point (Azevedo et al., 2017). According to Lado et al. (2018), the agricultural quality norms of the United Nations Economic Commission for Europe (UNECE) require a ratio of at least 6.5 for oranges. However, the values may vary from 6 to 20 for industrial processing (Negreiros et al., 2014). Therefore, all the rootstocks studied led to the formation of fruits with values above the established norms.

However, as a rule the quality of the scion fruit is affected by the rootstock, as determined in this study, Amorim et al. (2018) did not detect significant differences for the juice yield, acidity, soluble solids, ratio, or technological index characteristics of the 'Cara Cara' Bahia orange and the 'Tahiti CNPMF-02' acid lime grafted onto different rootstocks. Except for the juice yield, Sampaio et al. (2016) for the 'Pera' orange and Domingues et al. (2018) for the 'Cadenera' orange verified the influence of the rootstocks for these characteristics, also finding higher averages than observed in the present study.

Agricultural practices, environmental factors, and their interrelations influence fruit quality. It is believed that water relations, mineral nutrition, and hormones determine the

rootstock's influence on fruit quality (Lado et al., 2018). Combined with these factors, we may also cite those related to the root architecture and its capacity to explore the soil, and the shape the scion acquires upon being influenced by the rootstock.

Conclusions

There was an effect of the rootstocks on the agronomic performance of the 'Pera' orange.

The 'Santa Cruz Rangpur' lime, 'Indio' citrandarin, and the hybrid LVK x LCR - 038 rootstocks reflected the best performance of the 'Pera' orange. Therefore, they constitute an alternative to the 'Rangpur' lime and may be incorporated into the current orange production system of the region.

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