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Physico-chemical characterization of orange fruits on different rootstocks

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Abstract - The objective of this study was to evaluate the physico-chemical characteristics of fruits of 58 sweet orange tops cultivars on four rootstocks, namely: 'Sunki Tropical' mandarin and 'Trifoliata' Citrandarin 'San Diego', 'Riverside' and 'Indio'. For this purpose, a completely randomized experimental design was used, in a factorial scheme (58 x 4). The characteristics analyzed were: equatorial diameter, fruit mass, peel thickness, number of seeds, soluble solids, titratable acidity, Ratio and juice yield. All the characteristics analyzed were influenced by both the tops cultivar and the rootstock, demonstrating that both factors interfere in the physicochemical quality of the fruits. The tops 'Pera D-3', 'Pera Olimpia', 'Pera Bianchi', 'Jaffa' and 'Westin' on all rootstocks evaluated showed characteristics in their fruits with soluble solids greater than 10 ºBrix, Ratio above 9.5 and juice yield greater than 45%, characteristics that define fruits with quality standards. Also, the tops 'Pera Olimpia', 'Sincorá' and 'Westin' on the rootstock 'Sunki Tropical', 'Pera D-3', 'Pera D-25', 'Sincorá', 'Aquiri' and 'Russas P.S.' on the rootstock 'San Diego', 'Pera C-32', 'Pera D-3', 'Pera D-6', 'Pera E-6', 'Pera Bianchi', 'Pera CE-03 ', 'Salustiana' and 'Westin' on 'Riverside' rootstock are suitable for the juice production industry with Ratio between 14 and 16 and juice yield greater than 50%. It is also worth noting that the tops 'Crescent', 'Natal Folha Murcha', 'Valencia Midknight' and 'Valencia Delta' produced fruits without seeds on all rootstocks.

Index Terms: *Citrus* spp., fruit quality, cultivars, Genetical diversity.

Caracterização físico-química de frutos de laranjeira-doce sobre diferentes porta-enxertos

Resumo – Objetivou-se por este estudo avaliar as características físico-químicas de frutos de 58 cultivares de copa de laranjeiras-doce sobre quatro porta-enxertos, sendo eles: tangerineira 'Sunki Tropical' e os híbridos de 'Trifoliata' Citrandarin 'San Diego', 'Riverside' e 'Indio'. Para tanto, utilizou-se o delineamento experimental inteiramente ao acaso, em esquema fatorial (58 x 4). As características analisadas foram: o diâmetro equatorial dos frutos; a massa dos frutos; a espessura da casca;

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o número total de sementes; o teor de sólidos solúveis; a acidez titulável; *Ratio* e o rendimento de suco. Todas as características analisadas sofreram influência tanto da cultivar copa quanto do porta-enxerto, demostrando que os dois fatores interferem na qualidade físico-química dos frutos. As copas 'Pera D-3', 'Pera Olimpia', 'Pera Bianchi', 'Jaffa' e 'Westin', sobre todao os porta-enxertos avaliados, apresentaram características nos seus frutos com sólidos solúveis maior que 10 ºBrix, *Ratio* acima de 9,5 e rendimento de suco superior a 45%, características essas que definem frutos com padrão de qualidade. Também, as copas 'Pera Olimpia', 'Sincorá' e 'Westin' no porta-enxerto 'Sunki Tropical', 'Pera D-3', 'Pera D-25', 'Sincorá', 'Aquiri' e 'Russas P.S' no porta-enxerto 'San Diego', 'Pera C-32', 'Pera D-3', 'Pera D-6', 'Pera E-6', 'Pera Bianchi', 'Pera CE-03', 'Salustiana' e 'Westin', no porta-enxerto 'Riverside' mostram-se apropriadas para a indústria de produção de suco com *Ratio* entre 14 e 16 e rendimento de suco superior a 50%. Vale destacar, ainda, as copas 'Crescent', 'Natal Folha Murcha', 'Valencia Midknight' e 'Valencia Delta' que produziram frutos com ausência de sementes em todos os porta-enxertos.

Termo para indexação: *Citrus* spp., qualidade de frutos, cultivares, diversidade genética.

Introduction

The Brazil stands out internationally as the largest producer and main exporter of sweet orange juice [*Citrus × sinensis* (L.) Osbeck] (STUCHI et al., 2020), with its production distributed throughout all regions of the country due to its easy adaptation to the condition edaphoclimatic conditions (SIQUEIRA; SALOMÃO, 2017). In 2019, the country produced around 17,073,593 tons, with emphasis on the State of São Paulo, which contributed with more than 77% of all national production (IBGE, 2021).

The formation of seedlings for citrus orchards is usually done through grafting. About rootstocks, cultivars with dwarfing characteristics have been sought, that is, those materials that have a reduced size, in which greater productive efficiency is possible due to increased density and easier cultural practices, reducing production costs. In addition, the rootstock must have the tolerance to the main diseases, resistance to drought, frost, and compatibility with tops cultivars (BASTOS, et al., 2014). The materials used as rootstock also have a direct influence on the characteristics of the tops cultivars, interfering with vigor and productivity, in addition to affecting the fruits, maturation period, mass, shell color, sugar content, acidity, and juice quantity (POMPEU JUNIOR, 2005). In this sense, the hybrids of 'Trifoliata' Citrandarin 'Indio', 'Riverside', 'San Diego' and the mandarin tree 'Sunki Tropical' stand out as rootstocks (BASTOS, et al., 2014).

In Brazil, tops and rootstock cultivars have a narrow genetic base, limiting the expansion of the crop, therefore, there is a need to include new cultivars, in order to increase genetic diversity and minimize phytosanitary problems, in addition to meeting the demand of producers and consumers with more productive cultivars and better-quality fruits (MARTINS et al., 2014; BASTOS et al., 2015). Another problem related to the production of sweet orange trees is the low quality of the juice, often related to the Northeast Region, where the fruits of this region are stigmatized as not being able to meet the requirements of the consumer market.

Thus, it is necessary to carry out research that characterizes the various combinations of tops/rootstock cultivars of *Citrus* spp., which will serve as an alternative for consumers and farmers, enabling an increase in Brazilian production to serve the domestic and foreign markets. In this sense, the objective of this study was to evaluate the physicochemical characteristics of the fruits of 58 sweet orange tree tops cultivars, having 'Sunki Tropical' mandarin as rootstock and the hybrids of 'Trifoliata' Citrandarin 'San Diego', 'Riverside' and 'Indio'.

Material and methods

The study was conducted in 2021, in a 6-year-old citrus orchard located at the Chão Bello Farm, belonging to the Bello Brazilian Exotic Fruit Company, located in the municipality of Ibirapuã, in the extreme south of the State of Bahia, Brazil. Under the following conditions: geographic coordinates: 18° 03’ 09.4” South latitude, 39° 52’ 26.2” East longitude. The climate in the region, according to the Köppen classification, is Tropical Am (ALVARES et al., 2014). The maximum, average, and minimum temperatures (°C) (Figure 1), in addition to the daily average humidity (%) (Figure 2) during the experimental period were obtained from the National Institute of Meteorology (INMET) database, whose monitoring was carried out by an automatic meteorological station located in the municipality of São Mateus, in the north of the state of Espírito Santo.

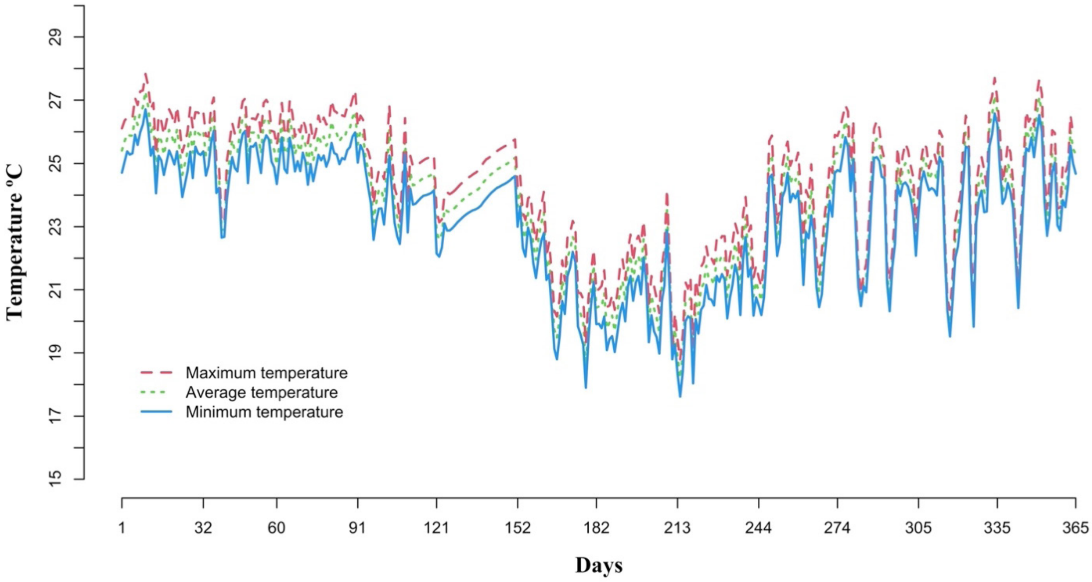

FIGURE 1. Maximum, average and minimum temperatures (ºC) during the experimental period obtained with an automatic meteorological station located in the municipality of São Mateus, North of the State of Espírito Santo.

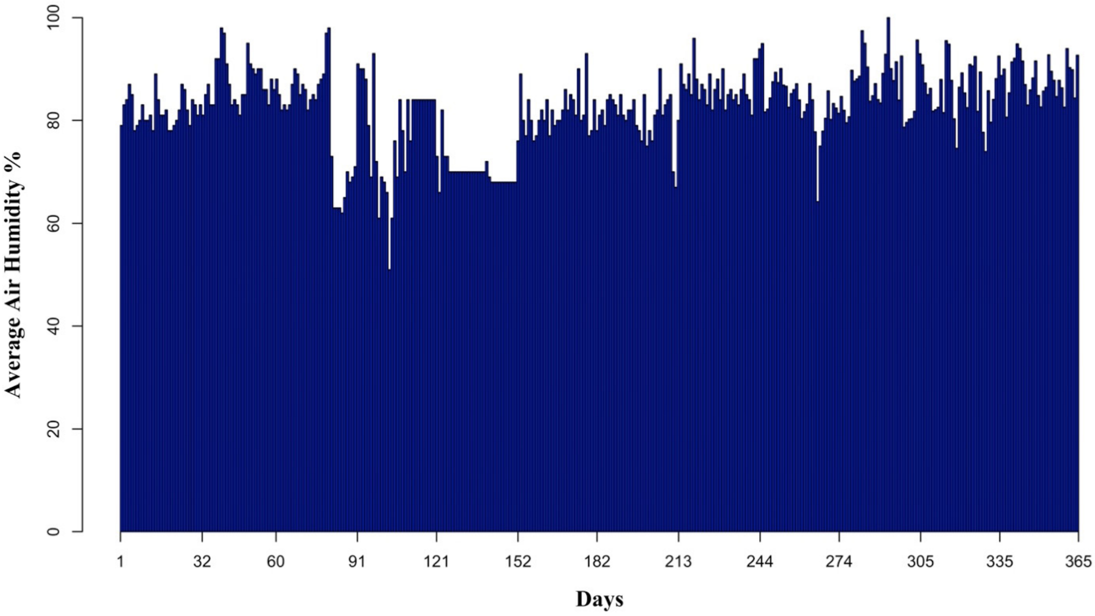

FIGURE 2. Relative humidity (average) of the air (%) during the experimental period obtained with an automatic meteorological station located in the municipality of São Mateus, North of the State of Espírito Santo.

The chemical characteristics of the soil in the experimental area in the 0-20 cm layer are shown in Table 1. Fertilizing was carried out through fertigation, the amount of which during the years 2020 and 2021 can be seen in Table 2.

TABLE 1. Soil chemical attributes in the experimental area of Fazenda Chão Bello, in the municipality of Ibirapuã, BA, at a soil depth of 0-20 cm

pH	MO	P	K	Ca	Mg	Al	H+Al	SB	T	V
(H_2O)	dag dm $^{-1}$	--- mg dm^{-3} ---		---------------- cmol$_c$ dm^{-3} ----------------						- % -
5,2	1.88	16	74	0.9	0.3	0.1	2.8	1.4	4.2	33.5

TABLE 2. Fertilizer, quantity (kg) and number of monthly applications in the years 2020 and 2021 in the experimental area of Fazenda Chão Bello, in the municipality of Ibirapuã, BA

Fertilizer	Quantity (kg)/number of applications (month^{-1})														
	2020											2021			
	Jan.	Feb.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	June	July	Aug.	Nov.
Urea	44/4	44/2	20/2	20/3	20/4	20/3	20/3	20/1	20/2	20/3	11/2	50/2	50/4	22/3	22/1
Potassium chloride	66/4	66/2	20/2	20/3	20/4	20/3	20/3	20/1	20/2	20/3	14.7/2			29.4/3	29.4/1
Calcium nitrate	33/4	33/2	10/2	10/3	10/4	10/3	10/3	10/1	10/2	10/3	13.2/2			26.4/3	26.4/1
Manganese sulfate	4.4/4	4,4/2													
Copper sulfate	4.4/4	4.4/2													
Zinc sulfate	5/4	5/2													
Magnesium nitrate	22/4	22/2													
Boric acid	1.1/2	1.1/1													

Planting was carried out on April 21, 2015, adopting a spacing of 6 meters between rows and 3 meters between plants. Irrigation was used with a localized microsprinkler type system, with a flow rate of 72 L/h, maintained by a KSB Meganorm 50-200 centrifugal pump with 40 hp and maximum operating pressure of 10 bar, divided into two fixed irrigation shifts of 6 mm/h. day. The monitoring of pests and diseases, as well as their control, in addition to all cultural treatments, were carried out according to the management established by the company Bello Brazilian Exotic Fruit, as described by Siqueira and Salomão (2017).

The experimental design used was completely randomized, in a factorial arrangement (58 x 4), where the first factor corresponds to 58 sweet orange tree tops cultivars: Pera (CNPMF selections 01, 02, A-15, B-12, L-21, L-32, L-3, L-6, L-9, L-12, L-25, L-3 ipeal and L-6, Olímpia, Bianchi, Ce-03, Vacinada, and Ibotirama) , Natal (CNPMF selections 01, 02 and 112, Ipeal and Folha Murcha), Valencia (CNPMF selections, 01, 02, 03, 21, 27, 36, F-11, Midknight, Criola, Delta, Late, L.Shaffey, Chapman, L.White, Montemorelos, Registro, Tuxpan), Berna, Jaffa, F-Menuda, Sincorá, Aquiri, Early Oblong, Russas P.S, Seleta de Itaboraí, Salustiana, Pineapple, Rubi CN-01, Westin, Diva, Hamlin CNPMF -20, Crescent, Melrosa and Flor de Brumadinho. The second factor was composed of four different rootstocks: the ‘Sunki’ mandarin tree, the ‘Sunki Tropical’ selection (*Citrus sunki* (Hayata) hort. ex Tanaka) and the ‘Trifoliata’ hybrids; Citrandarin ‘San Diego’, from the cross between the mandarin tree ‘Sunki’ *C. sunki* (Hayata) hort. ex Tanaka x *Poncirus trifoliata* (L.), ‘Riverside’, from the cross between the mandarin tree ‘Sunki’ *C. sunki* (Hayata) hort. ex Tanaka x *P. trifoliata* (L.) and ‘Indio’, from the cross between the mandarin tree ‘Sunki’ *C. sunki* (Hayata) hort. ex Tanaka x *P. trifoliata* (L.). Three experimental plots (plants) were evaluated, totaling 696 plants in the experimental field.

Samples containing 12 fruits were collected from the middle third of the canopy of the four cardinal points of 3 different plants (FERREIRA, 2022), which were packed in polyethylene bags and analyzed in the laboratory. The following were determined: the average fruit mass (FM), in g, with a precision electronic scale; the equatorial diameter of the fruits, in mm, and the peel thickness, in mm, using a digital caliper; in addition to the total number of seeds, obtained by counting the total number of seeds in the fruits.

Subsequently, the juice of the fruits was extracted with the aid of an industrial processor Skymsen model EXB-N from which the juice yield (JY) was determined from the juice mass (JM) measured on a precision electronic scale and the MF through the formula: JY = (JM/FM) x 100, the results being expressed in %. The soluble solids content (SS, ºBrix) was also determined through the fruit pulp juice and with the aid of a digital refractometer; the titratable acidity (TA, % citric acid), defined by titration of an aliquot of 10 mL of juice and three drops of 1% phenolphthalein with NaOH solution (0.1 N), previously standardized and Ratio given by the product of division of SS by AT.

The data were submitted to analysis of variance by the F test at 5% probability and their means were compared by the ScottKnott cluster test ($p < 0.05$). All statistical analyzes were obtained with the help of the software (R CORE TEAM, 2021), through a command developed for the ExpDex.pt data package (FERREIRA, et al., 2018).

Results and discussion

The temperature during the experiment ranged from 17.6 to 27.8ºC (Figure 1). These values are within the 13 to 32ºC range suggested by Siqueira and Salomão (2017) for better development in citrus crop. Still, according to the authors, under temperatures below 13ºC or above 35ºC, there is a decrease of the photosynthetic rate in orange trees by about 50%, which can interrupt development and significantly alter the characteristics of the plant, such as the size, shape of the leaves and the durability of the fruits.

For the mean relative humidity of the air, there was a variation from 51 to 100% (Figure 2). Periods of high mean relative humidity of the air may favor the incidence of diseases such as brown spot (*Alternaria alternata*), scab (*Elsinoe*), and citrus flower rot (*Colletotrichum*) (SIQUEIRA; SALOMÃO, 2017), however, the occurrence of these diseases were not observed of the present study. On the other hand, a period with a low mean relative humidity of air may imply changes in the acidity content and soluble solids in fruits, however, it is important to point out that the orchard under study is irrigated, and all moisture demand is met.

The summary of the analysis of variance representing the average square of the physical and chemical characteristics of the fruits of the 58 sweet orange tops cultivars on four rootstocks is shown in Table 3. It can be noted that there was a significant interaction between the factors for all the characteristics evaluated, demonstrating that both the tops cultivar and the rootstock interfered with the characteristics of the different combinations analyzed.

TABLE 3. Summary of the analysis of variance with the source of variation, degree of freedom (DF), average square and coefficient of variation (CV) for the characteristics: equatorial diameter (ED), fruit mass (FM), peel thickness (PT), number of seeds (NS), soluble solids (SS), titratable acidity (TA), Ratio and juice yield (JY)

Source of variation	DF	Average square							
		ED	FM	PT	NS	SS	TA	Ratio	JY
Tops	57	186.57*	0.0069*	4.68*	266.98*	5.39*	1.18*	76.25*	322.51*
Rootstocks	3	168.57*	0.0081*	10.26*	75.05*	5.43*	3.93*	173.77*	687.24*
Tops x Rootstocks	171	82.96*	0.0017*	1.87*	48.38*	2.77*	0.23*	17.65*	199.21*
Residual	464	10.52	0.0004	0.13	7.33	0.13	0.02	2.48	49.38
CV%		**4.49**	**9.82**	**8.99**	**33.09**	**3.31**	**12.27**	**15.7**	**12.66**

*Significant at 5% probability by the F test.

Regarding the equatorial diameter and fruit mass (Table 4), there was variation from 48.3 to 103.1 mm and from 0.352 to 0.105 g, respectively, in all combinations analyzed. The equatorial diameter of orange tree fruits is used as a form of classification, being defined as large those with a diameter greater than 71 mm, medium between 65 and 71 mm, and small, smaller than 65 mm. In addition, through the diameter, it is possible to obtain the number of fruits that each package contains since this information is mandatory for marketing (CEAGESP, 2011).

TABLE 4. Equatorial diameter (mm) and mass (g) of sweet orange fruits on the rootstocks 'Sunki Tropical' (ST), 'San Diego' (SD), 'Riverside' (R) and 'Indio' (I)

Tops	Equatorial diameter (mm)				Mass (g)			
	Rootstocks							
	ST	SD	R	I	ST	SD	R	I
Pera 01	73.96cA	64.16eB	66.20eB	63.33eB	0.146dA	0.157dA	0.179dA	0.152eA
Pera 02	67.33dA	70.36dA	68.36dA	67.40dA	0.186bB	0.147dC	0.163eC	0.220cA
Pera A-15	74.20cA	74.33cA	69.60dA	48.33fB	0.199bA	0.200bA	0.211cA	0.166eB
Pera B-12	65.33dA	67.73eA	57.40fB	71.06dA	0.149dA	0.182cA	0.176dA	0.174eA
Pera C-21	69.66dA	67.50eA	66.66eA	70.76dA	0.189bA	0.161dA	0.175dA	0.192dA
Pera C-32	67.86dA	72.10dA	73.46cA	74.60cA	0.175cA	0.174cA	0.165eA	0.198dA
Pera D-3	68.86dA	67.63eA	69.30dA	70.00dA	0.186bA	0.173cA	0.178dA	0.195dA
Pera D-6	68.90dA	67.46eA	72.66cA	61.70eB	0.195bA	0.172cA	0.175dA	0.182dA
Pera D-9	68.23dA	67.66eA	72.86cA	72.60cA	0.165cB	0.158dB	0.199dA	0.215cA
Pera D-12	66.00dB	103.13aA	65.93eB	69.26dB	0.183bA	0.148dA	0.168dA	0.184dA
Pera D-25	68.30dA	69.46dA	66.16eA	68.56dA	0.177cA	0.174cA	0.188dA	0.181dA
Pera E-6	72.03cA	65.60eB	71.80dA	72.53cA	0.160cB	0.178cA	0.142eB	0.181dA
Pera Olimpia	64.90dB	72.36dA	66.66eB	75.33cA	0.105eB	0.185cA	0.176dA	0.190dA
Pera Bianchi	71.43cA	67.36eA	71.60dA	71.33dA	0.200bA	0.182cA	0.171dA	0.197dA
Pera CE-03	74.00cA	66.30eB	66.36eB	74.86cA	0.195bA	0.159dB	0.203dA	0.211cA
Pera Vacinada	72.96cA	72.66dA	64.26eB	71.26dA	0.172cA	0.185cA	0.181dA	0.188dA
Pera E-3 Ipeal	72.46cA	67.13eB	65.40eB	76.90cA	0.173cA	0.184cA	0.148eA	0.166eA
Berna	70.86dB	70.43dB	72.70cB	78.30cA	0.179cB	0.184cB	0.148eC	0.235cA
Jaffa	76.83bB	71.66dC	79.10bB	86.20aA	0.202bB	0.185cB	0.230cA	0.259bA
F-Menuda	67.06dA	71.16dA	61.46fB	62.66eB	0.141dB	0.166dA	0.121eB	0.135eB
Sincorá	72.86cA	64.93eB	70.66dA	64.33eB	0.187bA	0.183cA	0.184dA	0.177dA
Aquiri	72.10cA	66.53eB	75.80cA	69.66dB	0.186bA	0.181cA	0.202dA	0.213cA
Early Oblong	70.46dA	64.13eA	65.70eA	66.00eA	0.173cB	0.190cB	0.148eC	0.228cA
Russas P.S	66.53dB	74.90cA	72.30cA	71.60dA	0.176cB	0.171cB	0.161eB	0.207cA
Pera Ibotirama	75.30cA	76.70cA	71.50dB	68.03dB	0.188bA	0.203bA	0.182dA	0.167eA
Seleta Itaborai	86.63aA	82.20bA	82.26bA	86.40aA	0.215aB	0.222bB	0.238cA	0.255bA
Salustiana	68.80dB	72.46dA	65.20eB	76.90cA	0.164cB	0.201bA	0.140eB	0.193dA
Pineapple	70.43dB	73.90cA	75.36cA	66.00eB	0.164cA	0.191cA	0.180dA	0.165eA
Rubi CN-01	71.16cB	71.90dB	78.36bA	76.46cA	0.173cB	0.195cB	0.223cA	0.206cA
Westin	75.80cA	74.60cA	66.70eB	74.66cA	0.209aA	0.190cA	0.171dA	0.185dA
Diva	73.13cA	74.03cA	74.13cA	77.60cA	0.198bB	0.211bB	0.275cA	0.209cB
Hamlin 20	70.30dB	72.76dB	78.46bA	76.90cA	0.203bA	0.208bA	0.204dA	0.192dA
Natal 01	68.36dB	76.76cA	65.46eB	72.60cA	0.159cB	0.213bA	0.139eB	0.169eB
Crescent	63.40dB	60.66eB	69.26dA	65.50eA	0.133dA	0.137dA	0.162eA	0.164eA
Natal 02	74.53cA	69.66dB	68.46dB	65.43eB	0.210aA	0.203bA	0.190dA	0.173eA

(to be continued)

TABLE 4. (Continuation)

Tops	Equatorial diameter (mm)				Mass (g)			
	Rootstocks							
	ST	SD	R	I	ST	SD	R	I
Natal Ipeal	76.73bA	76.90cA	68.00dB	78.26cA	0.221aA	0.202bA	0.169dB	0.178dB
Natal 112	73.43cB	79.46bA	72.26cB	76.90cA	0.187bB	0.229bA	0.177dB	0.178dB
Natal Folha Murcha	74.30cB	76.63cB	80.46bA	83.26bA	0.225aB	0.265aA	0.225cB	0.278bA
Valencia 01	79.26bA	75.56cA	70.00dB	76.90cA	0.183bB	0.217bA	0.187dB	0.223cA
Valencia 02	78.23bA	76.36cA	64.33eB	73.53cA	0.242aA	0.182cB	0.211cA	0.224cA
Valencia Cnpmf	65.63dB	71.26dA	73.96cA	62.76eB	0.172cA	0.204bA	0.177dA	0.176dA
Valencia 03	66.63dB	77.13cA	75.00cA	76.90cA	0.184bB	0.215bA	0.237cA	0.191dB
Valencia 27	67.40dB	67.50eB	74.76cA	66.76eB	0.184bB	0.182cB	0.160eB	0.220cA
Valencia 36	71.70cB	65.46eB	69.33dB	76.90cA	0.211aA	0.195cA	0.212cA	0.202dA
Valencia Midknight	74.66cC	72.26dC	81.53bB	88.20aA	0.228aC	0.248aC	0.298bB	0.336aA
Valencia F-11	66.13dC	75.50cB	90.36aA	72.30cB	0.201bB	0.188cB	0.352aA	0.214cB
Valencia Criola	73.13cA	75.70cA	75.26cA	76.63cA	0.194bA	0.196cA	0.177dA	0.191dA
Valencia Delta	73.40cB	77.10cB	76.93cB	83.53bA	0.202bA	0.209bA	0.224cA	0.224cA
Valencia Late	65.90dB	77.13cA	82.26bA	82.03bA	0.200bA	0.194cA	0.227cA	0.189dA
Valencia Shaffey	66.93dB	81.56bA	66.46eB	76.90cA	0.217aA	0.221bA	0.185dA	0.219cA
Valencia Chapman	71.46cB	72.46dB	64.53eC	79.03cA	0.198bA	0.188cA	0.161eB	0.217cA
Valencia L. White	75.46cA	70.46dA	76.93cA	76.53cA	0.188bB	0.177cB	0.215cA	0.236cA
Valencia Monemorelos	74.46cA	68.50eA	74.66cA	74.20cA	0.182bC	0.258aA	0.212cB	0.168eC
Valencia Registro	67.46dC	75.70cB	83.30bA	82.53bA	0.215aB	0.226bB	0.263cA	0.275bA
Valencia Tuxpan	71.53cB	79.66bA	72.46cB	81.00bA	0.177cB	0.244aA	0.197dB	0.231cA
Valencia 21	73.66cA	74.76cA	68.90dB	76.90cA	0.186bB	0.201bA	0.168dB	0.225cA
Mel Rosa	78.23bA	75.26cA	73.63cA	76.90cA	0.193bA	0.197cA	0.193dA	0.219cA
Flor Brumadinho	71.43cB	81.66bA	69.66dB	76.90cA	0.174cB	0.207bA	0.151eB	0.188dA

Means followed by the same lowercase in the column and uppercase letter in the row do not differ by the Scott-Knott mean cluster test at 5% probability.

Both the equatorial diameter and the mass of the fruits are directly related to the size of the fruits and, consequently, define their commercial destination. Fruits that are medium or large are preferably destined for the in natura market, and to meet the quality standards of this market, orange fruits must have an average diameter above 70 mm and an average mass of 152.5 g, on the other hand, small fruits are destined for the juice production industry (DOMINGUES et al., 2003; HUSSAIN et al., 2013).

For peel thickness, both the rootstock and the tops cultivars influenced in these characteristics, with a difference being observed in relation to the analyzed treatments (Table 5). According to Beber et al. (2018), a smaller peel thickness is sought in orange fruits, since these fruits have a better use, as they have a better juice yield. In addition, fruits with thinner skin are more desirable to in natura consumption, since of peeling process is facilitated, and the edible contents of the fruit is higher (SAU et al., 2018). In this way, the smallest thicknesses were verified in the cultivars Pera A-15, Pera B-12, Pera D-3, Pera D-6, Pera D-9, Pera D-25, Valencia Tuxpan in the rootstock 'Sunki Tropical' , Pera 02, Pera C-32, Pera D-3, Pera D-6, Pera D-9, Pera D-12, Pera Olimpia, Pera Bianchi, Pera Vacinada, Natal 01, Crescent, Natal 02, Valencia CNPMF in the rootstock 'San Diego', Pera A-15, Pera B-12, Pera C-21, Pera C-32, Pera D-6, Pera D-25, Pera E-6, Pera Olimpia, Pera Bianchi, Pera Vacinada , F-Menuda, Valencia Midknight on 'Riverside' rootstock and Pera 02, D-3 Pera, E-6 Pera, Bianchi Pera, Ce-03 Pera, Jaffa, Early Oblong on 'Indio' rootstock.

TABLE 5. Peel thickness (mm) and number of seeds of sweet orange fruits on the rootstocks 'Sunki Tropical' (ST), 'San Diego' (SD), 'Riverside' (R) and 'Indio' (I)

Tops	Peel thickness (mm)				number of seeds			
	Rootstocks							
	ST	SD	R	I	ST	SD	R	I
Pera 01	3.23gB	3.86dB	3.53eB	4.53bA	6.5dB	11.8cA	6.3dB	4.5eB
Pera 02	3.33gA	2.90eB	3.36eA	2.56dB	2.0eB	8.0dA	5.0eA	6.6dA
Pera A-15	2.96hA	3.40dA	3.00fA	3.50cA	9.2dA	6.5dA	3.7eA	8.0dA
Pera B-12	2.60hB	3.36dA	2.80fB	3.20cA	3.1eA	6.1dA	8.0dA	6.7dA
Pera C-21	3.53gA	3.53dA	2.50fB	3.10cA	8.6dA	6.7dA	9.1dA	6.3dA
Pera C-32	3.23gB	3.03eB	2.66fB	4.50bA	7.5dA	7.4dA	7.1dA	6.0dA
Pera D-3	3.03hA	2.40eB	3.40eA	2.50dB	9.5dB	16.8bA	6.1dB	7.3dB
Pera D-6	2.73hB	2.80eB	2.30fB	3.56cA	7.5dA	6.6dA	5.2eA	2.8eA
Pera D-9	3.00hB	2.46eC	3.46eB	4.40bA	11.1dA	5.6dB	5.0eB	5.0eB
Pera D-12	5.43cA	2.43eD	3.30eC	3.90cB	10.3dA	10.3dA	10.8dA	3.0eB
Pera D-25	3.13hA	3.63dA	2.46fB	3.53cA	9.0dA	4.5eB	6.7dA	2.0eB
Pera E-6	3.23gA	3.63dA	2.90fB	2.50dB	5.0eA	8.0dA	6.7dA	6.5dA
Pera Olimpia	4.36eA	2.83eC	2.56fC	3.60cB	4.8eA	6.6dA	7.0dA	8.5dA
Pera Bianchi	3.50gA	3.00eB	2.76fB	2.76dB	5.5eA	7.2dA	7.5dA	5.5eA
Pera CE-03	4.33eA	3.36dB	3.06eB	2.60dC	6.9dA	7.1dA	6.1dA	8.2dA
Pera Vacinada	3.56gA	2.40eB	2.80fB	3.30cA	5.5eA	5.0eA	7.5dA	7.6dA
Pera E-3 Ipeal	4.30eA	3.50dB	4.10dA	4.50bB	9.6dA	9.5dA	10.0dA	11.5dA
Berna	4.63dB	5.60bA	3.26eC	4.40bB	28.8aA	13.3cC	15.0cC	19.0cB
Jaffa	5.36cA	3.90dB	3.10eC	2.60dC	6.6dC	10.5dC	22.5aB	43.3aA
F-Menuda	3.83fA	3.70dA	2.40fB	3.40cA	12.25cB	16.4bA	18.5bA	15.8cA
Sincorá	4.30eB	5.30bA	3.06eC	4.46bB	7.5dB	1.7eC	2.7eC	14.3cA
Aquiri	4.40eA	3.63dB	3.76eB	4.76bA	20.4bA	15.9bA	18.0bA	17.6cA
Early Oblong	4.66dB	6.20aA	3.40eC	2.70dD	13.3cB	11.2cB	8.6dB	18.3cA
Russas P.S	4.43eA	4.50cA	4.63cA	3.70cB	11.1dB	13.5cB	21.8aA	24.0bA
Pera Ibotirama	5.36cA	4.63cB	3.46eC	3.10cC	14.8cC	36.6aA	14.6cC	20.6bB
Seleta Itaborai	7.53aA	4.83cC	4.46cC	5.30aB	12.6cA	8.9dA	9.8dA	11.5dA
Salustiana	3.96fA	4.36cA	3.30eB	3.66cB	2.3eB	12.7cA	1.8eB	3.6eB
Pineapple	4.23eA	3.23dB	4.16dA	4.50bA	9.9dB	6.0dB	12.8cA	15.0cA
Rubi CN-01	5.56cA	4.33cB	3.96dB	4.30bB	10.8dB	6.0dC	11.3dB	17.8cA
Westin	4.26eA	3.60dA	3.56eA	3.66cA	6.1dA	3.6eA	5.6eA	8.3dA
Diva	3.53gB	3.86dB	7.03aA	3.53cB	6.6dA	4.5eA	1.5eA	3.3eA
Hamlin 20	3.90fB	4.43cA	4.66cA	3.63cB	2.6eA	2.0eA	5.0eA	6.5dA
Natal 01	5.36cA	2.80eC	3.50eB	3.90cB	4.3eA	3.6eA	7.0dA	3.3eA
Crescent	4.33eA	2.56eB	4.20dA	4.33bA	2.0eA	3.5eA	3.1eA	3.5eA
Natal 02	5.33cA	3.10eC	3.66eC	4.40bB	4.0eA	2.8eA	3.8eA	7.0dA
Natal Ipeal	4.63dA	3.50dB	3.66eB	4.36bA	9.1dA	5.5dA	5.6eA	6.8dA
Natal 112	5.80bA	3.60dC	4.63cB	4.43bB	4.6eA	4.0eA	6.0dA	9.5dA
Natal Folha Murcha	4.73dA	3.36dB	4.60cA	4.10bA	3.5eA	2.0eA	3.0eA	3.0eA
Valencia 01	3.46gB	4.16cA	4.10dA	4.43bA	6.3dA	3.0eA	3.0eA	3.1eA
Valencia 02	5.26cA	3.46dC	4.40dB	3.76cC	8.6dA	5.8dA	9.5dA	9.3dA
Valencia Cnpmf	6.40bA	2.63eC	4.10dB	3.90cB	9.3dA	7.0dA	7.0dA	7.5dA
Valencia 03	4.26eB	5.16bA	5.13bA	4.43bB	5.6eA	7.1dA	5.3eA	6.1dA
Valencia 27	3.83fA	4.20cA	3.90dA	4.50bA	5.8eB	14.0cA	4.5eB	4.1eB

(to be continued)

TABLE 5. (Continuation)

Tops	Peel thickness (mm)				number of seeds			
	Rootstocks							
	ST	SD	R	I	ST	SD	R	I
Valencia 36	4.90dA	5.36bA	3.73eB	5.50aA	8.0dB	4.6eB	8.1dB	12.1dA
Valencia Midknight	4.00fB	6.30aA	2.50fC	3.46cB	2.3eA	3.0eA	2.0eA	0.0eA
Valencia F-11	4.80dA	4.53cB	5.10bA	4.10bB	6.6dB	5.5dB	24.6aA	8.7dB
Valencia Criola	6.30bA	4.53cB	4.30dB	3.20cC	2.3eA	2.0eA	2.0eA	6.0dA
Valencia Delta	6.26bA	4.53cB	3.53eC	3.66cC	1.0eA	1.1eA	0.3eA	1.8eA
Valencia Late	4.80dA	4.46cA	4.60cA	5.00aA	9.8dA	7.8dA	9.0dA	6.5dA
Valencia Shaffey	4.60dA	3.63dB	4.50cA	4.40bA	9.3dA	8.0dA	7.0dA	8.0dA
Valencia Chapman	3.63gA	3.23dA	3.10eA	3.33cA	6.3dA	5.8dA	6.5dA	2.0eA
Valencia L. White	3.43gB	4.30cA	4.66cA	3.36cB	6.5dA	6.0dA	4.0eA	6.0dA
Valencia Monemorelos	5.03dA	4.23cB	4.46cB	4.46bB	8.0dA	5.1dA	5.8dA	6.5dA
Valencia Registro	3.80fB	4.36cB	5.30bA	4.36bB	6.5dA	7.3dA	3.0eB	10.0dA
Valencia Tuxpan	3.10hB	4.30cA	4.76cA	3.30cB	7.5dB	12.0cA	7.0dB	4.5eB
Valencia 21	3.76fC	5.50bA	4.50cB	5.50aA	1.6eB	2.0eB	4.5eB	7.6dA
Mel Rosa	5.33cA	4.53cB	4.46cB	5.63aA	17.5bA	2.0eC	11.8dB	16.8cA
Flor Brumadinho	4.53dC	6.36aA	3.70eD	5.16aB	16.8bB	16.3bB	19.3bB	24.5bA

Means followed by the same lowercase in the column and uppercase letter in the row do not differ by the Scott-Knott mean cluster test at 5% probability.

For the number of seeds (Table 5), there was a significant difference between the treatments with mean values ranging from about 43 seeds per fruit in the Sincorá cultivar to the complete absence of seeds in the Valencia Midknight cultivar, both on the ‘Indio’ rootstock. A high number of seeds in orange fruits is undesirable when the objective is combinations that produce fruits for in natura market, as there is less acceptance by the consumer (LATADO et al., 2001). This characteristic is used to classify orange fruits into subgroups, being defined as the group with the presence of seeds and the group without the presence of seeds. For the second group, the occurrence of up to three seeds per fruit is eventually accepted (CEAGESP, 2011). Thus, from the studied combinations, the tops ‘Crescent’, ‘Natal Folha Murcha’, ‘Valencia Midknight’ and ‘Valencia Delta’ presented mean values below or equal to three viable seeds per fruit in all rootstocks.

For the soluble solids content represented by ºBrix (Table 6), there was a significant difference between the combinations with higher mean values for the cultivars Rubi, CN-01, Valencia CNPMF and Valencia 27 on the rootstock ‘Sunki Tropical’, Pera Vacinada and Pera E-3 Ipeal on ‘San Diego’ rootstock, Natal 01 and Mel Rosa on ‘Riverside’ rootstock and Pera C-32 on ‘Indio’ rootstock. The values obtained for the combinations that presented higher values of soluble solids, from 13.33 to 14.66 ºBrix, were higher than those observed by Buffon et al. (2021), from 7.9 to 12.07 ºBrix, for these same combinations. This fact is probably associated with climatic differences and the harvest period, resulting in a greater accumulation of soluble solids. Soluble solids represent about 80% of the sugars present in orange juice. Thus, there is a strong correlation between these factors, thus, the higher the sugar content, the greater the concentration of soluble solids present in the sample. Therefore, it is recommended fruit of the orange trees should be harvested when they reach a minimum value of 10 ºBrix for meet the market quality standard (SIQUEIRA; SALOMÃO, 2017).

TABLE 6. Soluble solids (º Brix) and titratable acidity of sweet orange fruits on the rootstocks 'Sunki Tropical' (ST), 'San Diego' (SD), 'Riverside' (R) and 'Indio' (I)

Tops	Sólidos Solúveis (º Brix)				Acidez Titulável			
	Rootstocks							
	ST	SD	R	I	ST	SD	R	I
Pera 01	11.70eA	10.30eB	11.53cA	10.70dB	1.5dA	1.0dB	0.9eB	1.4bA
Pera 02	9.70hC	11.50dA	10.46dC	10.50eB	1.3eA	0.9dB	1.0eB	0.7dC
Pera A-15	9.85hB	11.36dA	10.40dB	10.40eB	1.6dA	1.2dB	0.8fC	0.9C
Pera B-12	10.60fB	11.20dA	10.50dB	11.05dA	1.3eA	1.1dA	0.8fB	1.1cA
Pera C-21	10.03gC	11.43dA	10.70dB	10.95dB	1.3eA	0.8eB	0.7fB	1.3bA
Pera C-32	11.46eB	11.10dB	10.90dB	13.66aA	1.3eA	0.7eB	0.6fB	1.3bA
Pera D-3	12.66cA	11.50dB	10.45dC	11.20dB	0.9fA	0.6fB	0.7fB	0.9dA
Pera D-6	11.40eA	11.13dA	10.75dB	10.50eB	1.3eA	0.8eB	0.6fB	1.2cA
Pera D-9	10.70fC	11.66dB	12.50bA	10.70dC	0.9fA	0.8eA	1.0eA	1.1cA
Pera D-12	10.60fC	13.36bA	11.66cB	10.26eC	1.2eA	1.4cA	0.9eB	1.2cA
Pera D-25	11.53eA	11.63dA	11.05cA	11.53cA	1.3eB	0.8eC	0.9eC	1.6bA
Pera E-6	11.66eA	11.50dA	11.80cA	10.90dB	1.2eA	1.1dA	0.7fB	1.3bA
Pera Olimpia	12.33dA	11.56dB	10.60dA	10.33eC	0.8gA	0.8eA	0.6fB	0.9dA
Pera Bianchi	10.46fC	12.13cA	11.45cB	11.23dB	1.0fA	0.8eB	0.7fB	1.1cA
Pera CE-03	10.00gB	11.26dA	10.75dA	10.40eB	0.6hB	0.8eB	0.6fB	1.2bA
Pera Vacinada	9.55hC	14.60aA	10.76dB	11.03dB	0.8gB	1.4cA	1.0eB	1.2cA
Pera E-3 Ipeal	10.66fB	14.03aA	8.73fC	10.53eB	1.0fB	1.4cA	0.9eB	1.5bA
Berna	10.00gA	10.50eA	10.45dA	10.26eA	0.6hC	1.1dA	0.8fB	1.1cA
Jaffa	10.30gA	10.33eA	10.25dA	10.66dA	0.5hB	0.8eA	1.0eA	0.5eB
F-Menuda	8.93iB	10.03eA	9.35eB	10.40eA	1.0fB	0.7eC	0.8fC	1.5bA
Sincorá	13.43bA	10.63eB	9.50eC	10.40eB	0.9fA	0.7eA	0.8eA	0.9dA
Aquiri	9.53hA	10.26eA	10.10dA	9.90fA	1.0fA	0.6fB	0.7fB	1.2cA
Early Oblong	9.30iB	10.33eA	10.60dA	10.83dA	0.8gA	0.6fB	0.9eA	0.6eB
Russas P.S	11.53eA	10.23eC	9.73eC	10.76dB	1.1eA	0.7eB	1.0eA	1.1cA
Pera Ibotirama	10.13gB	9.66fC	9.55eC	10.73dA	0.9fA	0.5fB	0.8fA	1.1cA
Seleta Itaborai	10.46fB	11.06dA	9.30eC	11.36cA	1.0fA	0.5fB	0.7fB	1.0cA
Salustiana	10.06gB	8.80fC	10.40dB	11.13dA	0.8gB	0.5fB	0.7fB	1.1cA
Pineapple	10.10gA	10.26eA	9.70eA	9.90fA	1.0fB	0.8eB	1.0eB	1.4bA
Rubi CN-01	14.50aA	11.16dB	10.40dC	10.73dC	1.1eA	1.1dA	0.5fB	0.7dB
Westin	10.50fB	11.70dA	10.50dB	10.70dB	0.6hB	1.0dA	0.6fB	1.0cA
Diva	11.46eA	11.63dA	11.33cA	10.36eB	1.3eB	2.0aA	1.0eC	0.9dC
Hamlin 20	10.20gB	11.40dA	11.30cA	10.50eB	2.0cA	1.4cB	1.3dB	1.0cC
Natal 01	12.10dB	12.06cB	13.33aA	12.60bB	2.6aA	1.9aB	2.6aA	1.9aB
Crescent	13.40bA	13.10bA	12.16bB	12.43bB	1.4eA	1.6bA	1.3dB	1.0cC
Natal 02	12.30dA	11.53dB	10.50dC	10.66dC	1.9cA	1.8bA	1.0eC	1.4bB
Natal Ipeal	11.60eA	11.06dB	11.66cA	10.50eB	1.4eA	1.1dA	1.2dA	0.8dB
Natal 112	12.73cA	10.03eC	11.36cB	10.46eC	2.1bA	1.2cB	1.3dB	1.2cB
Natal Folha Murcha	9.53hC	11.50dA	10.40dB	11.10dA	2.0cA	1.1dC	1.6cB	1.4bB
Valencia 01	9.10iB	9.36fB	10.20dA	10.50eA	2.0cA	1.3cB	1.3dB	1.2cB
Valencia 02	10.16gC	10.13eC	11.46cA	10.80dB	1.2eB	0.9dC	1.2dB	1.9aA
Valencia Cnpmf	14.66aA	11.40dB	11.70cB	11.50cB	2.1bA	1.0dC	1.5cB	1.4bB
Valencia 03	10.53fA	10.76eA	10.53dA	10.53eA	1.6dA	1.5cA	0.9eB	1.2cB
Valencia 27	14.36aA	9.46fD	10.50dC	11.46cB	2.2bA	1.1dC	2.1bA	1.4bB

(to be continued)

TABLE 6. (Continuation)

Tops	Sólidos Solúveis (º Brix)				Acidez Titulável			
	Rootstocks							
	ST	SD	R	I	ST	SD	R	I
Valencia 36	11.16eA	11.30dA	9.46eC	10.43eB	1.5dA	1.1dB	1.1eB	1.5bA
Valencia Midknight	10.50fA	10.80eA	10.80dA	9.90fB	1.4eA	1.3cA	1.1eB	1.5bA
Valencia F-11	10.73fA	10.83eA	11.13cA	10.50eA	1.6dA	1.6bA	1.5cA	1.9aA
Valencia Criola	11.43eA	10.40eB	10.20dB	10.30eB	1.6dA	1.4cA	1.4cA	1.0cB
Valencia Delta	11.03eA	10.30eB	11.36cA	9.73fB	2.2bA	1.3cB	1.3dB	0.9dC
Valencia Late	11.56eB	9.56fC	12.16bA	12.53bA	2.2bA	1.6cB	1.4dB	1.1cC
Valencia Shaffey	10.66fB	10.40eB	10.33dB	11.53cA	1.9cA	1.5cB	1.1eC	1.5bB
Valencia Chapman	10.43fB	10.46eB	9.50eC	11.46cA	1.9cA	1.0dC	1.7cA	1.4bB
Valencia L. White	11.56eA	11.53dA	11.50cA	10.63dB	2.0cA	1.6cB	1.0eC	1.1cC
Valencia Monemorelos	10.23gB	10.80eB	12.13bA	10.46eB	2.0cA	1.3cB	0.9eC	1.4bB
Valencia Registro	10.26gB	10.46eB	10.43dB	11.23dA	2.0cA	1.5cB	1.0eC	1.3bB
Valencia Tuxpan	12.36dB	13.40bA	9.83eD	10.63dC	1.6dA	1.3cB	1.7cA	1.4bB
Valencia 21	10.20gC	11.40dB	12.33bA	9.43fD	2.0cA	1.4cB	1.2dB	1.2cB
Mel Rosa	13.60bA	12.13cB	13.53aA	12.50bB	1.3eA	1.5cA	1.1eB	1.3bA
Flor Brumadinho	13.13cA	11.46dB	9.93eC	9.70fC	1.0fA	0.9dA	0.7fA	0.8dA

Means followed by the same lowercase in the column and uppercase letter in the row do not differ by the Scott-Knott mean cluster test at 5% probability.

In the present study, the combinations that did not reach the minimum value recommended for soluble solids were: ‘Pera 02’, ‘Pera A-15’, ‘Pera Vacinada’, ‘F-Menuda’, ‘Aquiri’, ‘Natal Folha Murcha ‘ and ‘Valencia 01’ on the rootstock ‘Sunki Tropical’, ‘Pera Ibotirama’, ‘Salustiana’, ‘Valencia 01’ and ‘Valencia 27’ on the rootstock ‘San Diego’, ‘Pera E-3 Ipeal’ , ‘F-Menuda’, ‘Sincorá’, ‘Russas P.S’, ‘Pera Ibotirama’, ‘Seleta Itaborai’, ‘Pineapple’, ‘Valencia 36’, ‘Valencia Chapman’, ‘Valencia Tuxpan’ and ‘Flor Brumadinho ‘ on the rootstock ‘Riverside’ and ‘Aquiri’, ‘Pineapple’, ‘Valencia Midknight’, ‘Valencia Delta’, ‘Valencia 21’ and ‘Flor Brumadinho’ on the rootstock ‘Indio’. This fact may be associated with high water availability during the fruit formation period (RODRIGUES et al., 2019b). Furthermore, according to Lado et al. (2018) there is a possibility that lower values of soluble solids are related to increase in juice yield in the fruits.

Regarding the titratable acidity (Table 6), there was a statistical difference between the treatments where the mean values varied between the combinations of 2.6 to 0.5% of citric acid. These results show greater amplitude than those obtained by Buffon et al. (2021), who reported a variation from 0.36 to 1.47% of citric acid in 57 orange tree tops on four rootstocks. With the maturation of the orange fruits, there is a decrease in acidity, and this factor is related to the respiration process of the fruits since organic acids are used that are converted into sugars. However, the fruits should not have an acid content lower than 0.5 and 0.75% for industry and for in natura consumption, respectively, since very low values are not desirable as they result in a tasteless fruit (BEBER et al., 2018; RODRIGUES et al., 2019a).

Thus, as it is a noticeable characteristic by the consumer market, acidity becomes one of the main parameters of fruit quality, with values ranging from 0.9 to 0.6% of citric acid being adequate (POZZAN; TRIBONI, 2005). In this way, the tops cultivars Pera D-3, Pera Olimpia, Sincorá and Early Oblong stand out, which presented average values within the quality standards in all the rootstocks analyzed. However, it is worth mentioning that only the acidity evaluated individually did not should be used to define the best quality standard.

Regarding the Ratio (Table 7), the combinations that presented the highest mean values were the tops ‘Pera CE-03’, ‘Berna’, ‘Jaffa’ and ‘Westin’ on the rootstock ‘Sunki Tropical’, tops ‘Pera D-3’, ‘Early Oblong’, ‘Pera Ibotirama’, ‘Seleta Itaborai’ and ‘Salustiana’ on ‘San Diego’ rootstock, ‘Pera Olimpia’ and ‘Rubi CN-01’ on ‘Riverside’ rootstock ‘ and ‘Jaffa’ tops on ‘Indio’ rootstock. The relationship between soluble solids and acidity is an important parameter that defines the quality of orange fruits tree. As a minimum quality requirement for sweet orange fruits tree intended in natura consumption, Ratio values should not be less than 9.5 (CEAGESP, 2011). In this way, we must highlight the cups ‘Pera D-3’, ‘Pera Olimpia’, ‘Pera Bianchi’, ‘Jaffa’, ‘Sincorá’, ‘Early Oblong’, ‘Pera Ibotirama’, ‘Seleta Itaborai’, ‘Rubi CN -01’, ‘Westin’ and ‘Flor Brumadinho’ which presented mean values for the Ratio superior to the minimum standard of quality in all the analyzed rootstocks. These results corroborate those obtained by Buffon et al. (2021), who state that these combinations, except for the ‘Jaffa’ tops on the ‘Indio’ rootstock, presented minimum quality standards required by in natura market.

TABLE 7. Ratio and juice yield (%) of sweet orange fruits on the rootstocks ‘Sunki Tropical’ (ST), ‘San Diego’ (SD), ‘Riverside’ (R) and ‘Indio’ (I)

Tops	Ratio				Juice yield (%)			
	Rootstocks							
	ST	SD	R	I	ST	SD	R	I
Pera 01	7.55dB	10.03cA	12.01cA	7.67eB	59.40bA	54.99bA	62.56cA	53.83dA
Pera 02	7.43dB	11.94bA	9.99dB	13.77cA	58.00bB	64.99aB	80.16bA	58.64dB
Pera A-15	6.04eC	9.38cB	12.58cA	12.72cA	61.68bA	63.81aA	47.10dB	56.60dA
Pera B-12	7.77dB	10.25cB	12.91cA	9.60dB	50.97cB	49.43bB	64.57cA	54.70dB
Pera C-21	7.38dB	13.14bA	14.37cA	8.38dB	52.17cA	52.06bA	57.86cA	59.60dA
Pera C-32	8.51dC	13.96bB	16.93bA	10.22dB	66.60aA	51.80bA	61.56cA	64.45cA
Pera D-3	13.02cB	16.64aA	14.76bA	13.03cB	56.70bA	58.23bA	55.40cA	54.61dA
Pera D-6	8.42dB	13.94bA	16.12bA	8.50dB	57.17bA	58.95bA	59.57cA	58.55dA
Pera D-9	11.11cA	13.50bA	11.72cA	9.23dB	64.85aB	63.13aB	88.87aA	61.67cB
Pera D-12	8.76dB	9.32cB	12.04cA	8.78dB	45.47cA	47.37bA	43.56dA	54.29dA
Pera D-25	8.81dC	14.54bA	11.63cB	7.09eC	62.05bA	53.25bA	58.76cA	50.54dA
Pera E-6	9.73dB	10.43cB	15.91bA	8.37dB	78.94aA	51.47bB	54.20cB	67.67cA
Pera Olimpia	15.28bB	13.68bB	18.45aA	11.39cC	73.69aA	54.04bB	56.58cB	63.93cA
Pera Bianchi	10.59cB	13.94bA	15.85bA	9.53dB	60.86bA	49.95bA	58.64cA	58.53dA
Pera CE-03	16.93aA	12.98bB	15.70bA	8.00eC	54.69bA	63.54aA	58.64cA	59.91dA
Pera Vacinada	11.25cA	10.68cA	9.99dA	9.01dA	54.68bB	68.77aA	54.47cB	70.84cA
Pera E-3 Ipeal	10.40cA	9.60cA	9.19dA	7.00eA	52.45cA	49.41bA	44.57dA	42.99dA
Berna	17.87aA	9.26cC	12.41cB	9.07dC	53.06cA	50.65bA	51.60dA	49.70dA
Jaffa	19.10aA	12.96bB	11.06dB	20.35aA	54.44bA	52.00bA	47.35dA	48.21dA
F-Menuda	8.27dB	13.27bA	10.95dA	7.04eB	66.31aA	55.80bB	53.44cB	46.91dB
Sincorá	14.33bA	14.58bA	10.70dB	13.16cA	55.26bA	53.43bA	58.73cA	37.53dB
Aquiri	9.26dB	15.62bA	13.28cA	8.31dB	51.77cA	51.54bA	52.40dA	49.72dA
Early Oblong	11.22cB	18.53aA	11.05dB	16.98bA	52.46cA	55.85bA	52.55dA	54.77dA
Russas P.S	9.95dB	14.23bA	9.63dB	9.15dB	51.22cA	61.43aA	55.82cA	56.21dA
Pera Ibotirama	10.78cB	19.06aA	11.47dB	9.63dB	43.65cA	56.67bA	47.75dA	53.85dA
Seleta Itaborai	10.20cB	20.08aA	12.29cB	11.21cB	55.11bA	50.35bA	50.11dA	53.23dA
Salustiana	12.05cC	17.90aA	14.63bB	10.06dC	54.97bA	50.56bA	59.03cA	60.49dA
Pineapple	10.70cA	12.38bA	9.50dA	6.82eB	52.19cB	67.46aA	53.66cB	50.81dB

(to be continued)

TABLE 7. (Continuation)

Tops	Ratio				Juice yield (%)			
	Rootstocks							
	ST	SD	R	I	ST	SD	R	I
Rubi CN-01	12.99cB	10.10cC	19.34aA	13.93cB	29.19dB	52.95bA	46.23dA	53.26dA
Westin	16.67aA	11.36cB	15.93bA	10.27dB	52.91cB	62.20aA	54.98cB	70.51cA
Diva	8.82dA	5.71dB	10.38dA	10.89cA	58.90bA	36.37bB	56.97cA	65.14cA
Hamlin 20	5.05eB	7.76dA	8.32dA	9.90dA	59.96bA	53.95bA	48.92dA	62.69cA
Natal 01	4.62eA	6.12dA	5.01eA	6.45eA	45.02cA	57.59bA	54.95cA	45.89dA
Crescent	8.98dB	7.89dB	9.35dB	12.02cA	42.58cA	48.44bA	44.29dA	51.12dA
Natal 02	6.22eB	6.38dB	9.72dA	7.59eB	28.97dB	55.31bA	59.48cA	47.78dA
Natal Ipeal	7.91dB	9.43cB	9.08dB	12.06cA	53.21cB	69.13aA	51.36dB	69.61cA
Natal 112	5.89eA	7.90dA	8.36dA	8.41dA	47.59cA	60.68aA	54.22cA	51.44dA
Natal Folha Murcha	4.62eB	10.38cA	6.49eB	7.82eA	52.52cA	57.45bA	55.40cA	55.80dA
Valencia 01	4.55eB	6.94dA	7.86eA	8.57dA	72.91aA	55.84bB	49.34dB	72.95cA
Valencia 02	8.21dA	10.79cA	9.34dA	5.43eB	51.61cB	73.83aA	54.33cB	48.68dB
Valencia Cnpmf	6.78eB	10.48cA	7.60eB	7.92eB	46.97cA	57.65bA	59.84cA	52.06dA
Valencia 03	6.50eB	7.13dB	11.08dA	8.87dA	50.69cA	50.28bA	47.19dA	59.49dA
Valencia 27	6.53eB	8.56dA	4.79eB	7.95eA	48.08cB	66.77aA	54.60cB	55.67dB
Valencia 36	7.10dA	9.96cA	8.53dA	6.88eA	49.63cA	58.90bA	51.58dA	61.29cA
Valencia Midknight	7.08dA	7.94dA	9.68dA	6.58eA	53.72cA	49.38bA	58.72cA	62.82cA
Valencia F-11	6.38eA	6.42dA	7.00eA	5.62eA	43.22cB	67.82aA	55.34cB	53.62dB
Valencia Criola	7.10dA	7.44dA	6.91eA	9.47dA	49.89cA	55.27bA	59.15cA	56.70dA
Valencia Delta	4.99eB	7.90dA	8.52dA	10.45dA	46.94cC	76.91aB	47.58dC	81.01aA
Valencia Late	5.24eB	5.89dB	8.64dA	11.18cA	33.79dB	57.99bA	56.05cA	50.17dA
Valencia Shaffey	5.71eA	6.96dA	9.22dA	7.73eA	41.19dC	69.37aA	58.13cB	76.53bA
Valencia Chapman	5.42eB	9.59cA	5.40eB	8.12eA	61.11bA	61.12aA	50.46dB	47.21dB
Valencia L. White	5.76eB	7.11dB	10.49dA	9.16dA	56.20bA	42.41bA	49.97dA	54.46dA
Valencia Monemorelos	5.00eC	7.76dB	12.29cA	7.43eB	61.13bA	61.40aA	50.88dA	50.93dA
Valencia Registro	5.10eB	6.61dB	9.73dA	8.23dA	43.54cA	56.03bA	51.68dA	58.24dA
Valencia Tuxpan	7.39dB	10.00cA	5.73eB	7.29eB	46.74cA	49.72bA	50.66dA	56.20dA
Valencia 21	5.18eB	7.88dA	9.65dA	7.89eA	61.68bB	56.92bB	48.15dB	79.90bA
Mel Rosa	9.74dB	7.70dB	12.09cA	9.44dB	49.27cB	54.22bB	45.02dB	64.02cA
Flor Brumadinho	13.01cA	11.68bA	13.75cA	11.38cA	38.26dB	59.40aA	48.15dA	50.51dA

Means followed by the same lowercase in the column and uppercase letter in the row do not differ by the Scott-Knott mean cluster test at 5% probability.

For fruits intended for the juice production industry, priority should be given to cultivars with a Ratio between 14 and 16 (SIQUEIRA; SALOMÃO, 2017), what can be found in the tops cultivars Pera Olimpia, Sincorá and Westin on the rootstock ‘Sunki Tropical’, Pera D-3, Pera D-25, Sincorá, Aquiri and Russas P.S on the rootstock ‘San Diego’, Pera C-32, Pera D-3, Pera D-6, Pera E-6, Pera Bianchi, Pera CE-03, Salustiana and Westin on ‘Riverside’ rootstock.

As they are non-climacteric, oranges tree fruits stop ripening after being removed from the plants, so it is important that they be harvested when they reach an adequate relationship between content sugar and acidity (SIQUEIRA; SALOMÃO, 2017). Thus, the Ratio is the most reliable characteristic to define the fruit maturation point and consequently the ideal harvest period (COELHO et al., 2019).

For juice yield (Table 7), the combinations that were statistically superior were 'Pera D-32', 'Pera E-6', 'Pera Olimpia', 'F-Menuda', 'Valencia 01' on the rootstock 'Tropical Sunki', 'Pera A-15', 'Pera CE-03', 'Pera Vacinada', 'Russas P.S', 'Pineapple', 'Westin', 'Natal Ipea', 'Natal 112', ' Valencia 02', 'Valencia 27', 'Valencia F-11', 'Valencia Shaffey', 'Valencia Chapman', 'Valencia Monemorelos' on rootstock 'San Diego', 'Pera D-9' on rootstock ' Riverside' and 'Valencia Delta' on 'Indio' rootstock.

The minimum percentage of juice required to define fruit quality may vary according to the variety of the oranges tree: 35% for 'Hamlin', 'Bahia', and 'Lima', 40% for 'Rubi', 44% for 'Natal' and 'Valencia ' and 45% for 'Pera'. However, for orange fruits destined for the juice production industry, the recommended cultivars that have a juice yield greater than 50% (SIQUEIRA; SALOMÃO, 2017), and small changes in this content can directly influence the final yield and, consequently, the profitability of the sector (SIQUEIRA; SALOMÃO, 2017; BUFFON, 2020). In this way, the higher the juice yield, the more desirable the cultivar will be for both the in natura market and the industry (COELHO et al., 2019).

Thus, as shown in the present study, the quality characteristics of fruits sweet orange tree of tops cultivars are directly influenced by the rootstock used (AMORIM et al., 2018). Different rootstocks can influence the maturation period and fruit quality, productivity, resistance, or tolerance to pests and diseases and the different climate and soil conditions, in addition to interfering with metabolic processes such as photosynthesis (MATTOS JÚNIOR et al., 2005b).

In general, plants with high productivity are sought in combinations of tops and rootstock, and orange fruits intended for industry with high juice yield, good ratio between soluble solids and acidity, attractive color, in addition to these characteristics. When the objective is In natura consumption, characteristics that allow greater acceptance by consumers, such as fruit size, roughness, peel thickness, absence of seeds, facilitated peeling, pulp and peel color, and flavor, must be taken into account (SIQUEIRA; SALOMÃO, 2017).

For the juice industry we recommend the cultivars Pera Olimpia, Sincorá and Westin on 'Sunki Tropical' rootstock, Pera D-3, Pera D-25, Sincorá, Aquiri and Russas P.S on 'San Diego' rootstock, Pera C-32, Pera D-3, Pera D-6, Pera E-6, Pera Bianchi, Pera CE-03, Salustiana and Westin on 'Riverside' rootstock, all these combinations showed juice yield greater than 50%.

However, as 232 combinations were evaluated, other cultivars should be considered according to the intended market, such as those that produce fruits with lower skin thickness and a low number of seeds, for consumption In natura. Therefore, it is up to the producer and/or researcher to define which combination best meets the needs of the region and the consumer market.

Conclusions

The combinations 'Pera D-3', 'Pera Olimpia', 'Pera Bianchi', 'Jaffa', and 'Westin' provided fruits with soluble solids content, Ratio, and juice yield with commercial quality in all evaluated rootstocks.

The cultivars Pera Olimpia, Sincorá and Westin on 'Sunki Tropical' rootstock, Pera D-3, Pera D-25, Sincorá, Aquiri and Russas P.S on 'San Diego' rootstock, Pera C-32, Pera D- 3, Pera D-6, Pera E-6, Pera Bianchi, Pera CE-03, Salustiana and Westin on 'Riverside' rootstock are suitable for the juice production industry with Ratio between 14 and 16 and juice yield greater than 50%.

The tops 'Crescent', 'Natal Folha Murcha', 'Valencia Midknight', and 'Valencia Delta' produced fruit without seeds on all rootstocks.

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