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Artigo/Article

Performance of Pera sweet orange clones in clay soils in Southern Brazil

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SUMMARY

Pera sweet orange [*Citrus sinensis* (L.) Osbeck] is the main cultivar for the Brazilian citrus industry, with a few clones and selections available for growers. Furthermore, it may perform in different ways considering tree yield and fruit quality because of geographic regions. Therefore, the objective of this study was to evaluate clones of Pera sweet orange under a clay soil condition in Southern Brazil. The clones of Pera studied were: IPR 153 (Bianchi), Pêra CNPMF D6 (I-111), IPR 159 (Vacinada 4), IPR 158 (Vacinada 3), Morretes (I-34), Gullo (I-87), Vimusa (I-66), Seleção 12 (I-403), Seleção 27 (I-404), Seleção 11 (I-405), Seleção 14 (I-406), Seleção 15 (I-407) and Seleção 37 (I-408). All trees were grafted on Rangpur lime (*C. limonia* Osbeck) and the orchard was established on August 2000. The experimental design was completely randomized with thirteen treatments, five replications and one tree per plot. Tree vigor, yield and fruit characteristics were evaluated from 2003 through 2010. Seleção 27 had both the largest canopy with a volume of 54.5 m^3 and the highest yield, with an annual average yield of 107.5 kg of fruits per tree. In addition to Seleção 27, Seleção 12 and Morretes were also highly productive. Clones D-6 (I-111), IPR 158, IPR 159, Gullo (I-87), Seleção 14 (I-406), and Seleção 37 (I-408) had the best fruit quality for industrial purposes. Based on theoretical estimated values, Morretes, Seleção 12, Vimusa, and Seleção 27 showed potential yield higher than 1,200 boxes of fruits (40.8 kg) ha^{-1}.

Index terms: *Citrus sinensis*, yield, fruit quality, physicochemical analysis.

Desempenho de clones de laranja Pêra em solo argiloso no sul do Brasil

RESUMO

A laranja Pêra [*Citrus sinensis* (L.) Osbeck] é a principal cultivar para a indústria cítrica brasileira, com alguns clones e seleções disponíveis para os produtores. Além disso, pode diferir seu desempenho, considerando a produtividade das plantas e a qualidade das frutas, em função da região geográfica. Portanto, o objetivo deste estudo foi avaliar clones de laranja Pêra sob condição de solo argiloso, no sul do Brasil. Os clones de Pêra estudados foram: IPR 153 (Bianchi), Pêra CNPMF D6 (I-111), IPR 159 (Vacinada 4), IPR 158 (Vacinada 3), Morretes (I-34), Gullo (I-87), Vimusa (I-66), Seleção 12 (I-403), Seleção 27 (I-404), Seleção 11 (I-405), Seleção 14 (I-406),

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Seleção 15 (I-407) e Seleção 37 (I-408). Todas as plantas foram enxertadas em Limão Cravo (*C. limonia* Osbeck) e o pomar foi estabelecido em agosto de 2000. O delineamento experimental foi inteiramente casualizado, com treze tratamentos, cinco repetições e uma planta por parcela. O vigor das plantas, a produtividade e as características das frutas foram avaliados de 2003 a 2010. A Seleção 27 teve tanto a maior copa, com um volume de 54,5 m^3, quanto a maior produção, com produtividade média anual de 107,5 kg de frutos por planta. Além da Seleção 27, Seleção 12 e Morretes também foram altamente produtivos. Os clones D-6 (I-111), IPR 158, IPR 159, Gullo (I-87), Seleção 14 (I-406) e Seleção 37 (I-408) apresentaram a melhor qualidade de frutas para fins industriais. Com base em valores teóricos estimados, Morretes, Seleção 12, Vimusa e Seleção 27 apresentaram produtividade potencial superior a 1.200 caixas (de 40,8 kg) ha^{-1}.

Termos para indexação: *Citrus sinensis*, produtividade, qualidade do fruto, análise físico-química.

INTRODUCTION

Brazil is the largest sweet orange [*Citrus sinensis* (L.) Osbeck] producer in the world, with over 430 million boxes (40.8 kg) produced in the harvest of 2013, from an area of 702,000 ha (FAO, 2013). The State of São Paulo is responsible for nearly 75% of the total Brazilian sweet oranges production (IBGE, 2013). Besides São Paulo, the States of Bahia, Paraná, Minas Gerais, and Sergipe also have an important role in the Brazilian citrus industry for both, the fresh fruit market and industrial processing (IBGE, 2013).

Despite of the importance of the Brazilian citrus industry, the number of cultivars planted commercially is very limited (Auler et al., 2014). Further, Pera is by far the most important cultivar, comprising more than 33% and 45% of the sweet orange trees at São Paulo and Paraná States, Brazil, respectively (FUNDECITRUS, 2015; Auler et al., 2014). Fruits of Pera cultivar are highly prized due to the qualities for the fresh market and industial processing (FUNDECITRUS, 2015). Therefore, the large number of Pera trees poses a unique opportunity for selection of new superior clones of this sweet orange cultivar. Further, due to the highly diverse environmental conditions where citrus is cultivated in Brazil, it is of utmost importance to identify the best adapted citrus clones and cultivars to each citrus growing area around the country (Salibe et al., 2002; Donadio et al., 1995). Thus, it is necessary to consider several parameters for the selection of the best citrus clones and cultivars, such as tree growth and yield, fruit quality and harvesting time (Salibe et al., 2002; Donadio et al., 1995).

The objective of this study was to identify clones of Pera sweet orange with high potential of productivity and superior agronomic characteristics, and consequently better adapted to the clay soil conditions in Southern Brazil. Thirteen pre-selected clones of Pera were evaluated in regard to agronomic characteristics, including tree vigor and yield, and fruit quality.

MATERIALS AND METHODS

Field trial and genetic material

The study was carried out in Londrina, Paraná, Brazil, at altitude of 585 m, latitude of 23°22’S and longitude of 51°10’W, on a Typic Hapludox soil (NRCS, 1999). The climate is Cfa type, a humid subtropical climate, according to Köppen-Geiger classification, with average annual maximum and minimum temperatures of 27.3 °C and 16.1 °C, respectively, total annual average rainfall of 1,605 mm and average relative humidity of 70.4% (IAPAR, 2015).

The experimental orchard was planted on August 2000, in the spacing of 7.0 m × 6.0 m, corresponding to 238 trees ha^{-1}. The trees were not irrigated and both, phytosanitary and fertilization practices were carried out according to the recommendations for citrus production in the State of Paraná (IAPAR, 1992). Weeds were controlled by using an ecological rotary mower. The clones of Pera included in this study were pre-selected from the Active Citrus Germplasm Bank (AGB-Citrus) of the Agronomic Institute of Paraná (IAPAR). The clones included in the study were the following: IPR 153, IPR 159 and IPR 158, corresponding respectively to Bianchi, Vacinada 4, and Vacinada 3 (Tazima et al., 2010) and introduced originally from the Júlio de Mesquita Filho Agronomic Science Faculty/UNESP, Botucatu, State of São Paulo; D-6 (I-111) from EMBRAPA/CNPMF, Cruz das Almas, State of Bahia; Gullo (I-87) and Vimusa (I-66) from the IAC/ Sylvio Moreira Advanced Citrus Technology Research and Agribusiness Center, Cordeirópolis, State of São Paulo; and Morretes (I-34) from Morretes Experimental

Station, Agronomic Institute of Paraná - IAPAR, State of Paraná. The Pera sweet oranges Seleção 11 (I-405), Seleção 12 (I-403), Seleção 14 (I-406), Seleção 15 (I-407), Seleção 27 (I-404), and Seleção 37 (I-408) are selections of our own breeding program. All the clones of Pera were grafted on the rootstock Rangpur lime (*C. limonia* Osbeck).

Evaluations of tree vigor, yield and fruit characteristics

The vigor of the citrus trees was determined for the 2010 season, based on tree height and canopy diameter, measured with a graduated scale along the row and perpendicular to the row. Canopy volume was calculated by using the following equation: $V=2/3\pi R^2H$, where V = volume (m^3); π = 3.1416; *R* = canopy radius and H = tree height (Mendel, 1956).

Tree yield was determined by counting and weighting all the fruits at the harvesting time, on the month of August of each year, for the period from 2003 through 2010. Yield efficiency, expressed in kilogram of fruits per cubic meter of canopy volume, was determined by combining the harvests from 2003 through 2006 and from 2007 through 2010.

Fruit characteristics were evaluated based on a sample of 10 fruits per each plot, picked in the outer part of the tree at 1.0 to 2.0 m high, on the month of August of each year, for the period from 2006 through 2010. Average fruit weight was calculated by dividing the total weight by the number of fruits produced by each tree. Fruit height and diameter were determined using a digital vernier caliper, and classified according to the Sweet Orange (*Citrus sinensis* L. Osbeck) Classification (CEAGESP, 2000). The juice was extracted using a juice extractor. The juice yield was expressed in percentage determined by the equation: (WJ/WF) × 100, where WJ = weight of juice (g) and WF = weight of fruit (g). The number of seeds was determined by counting the seeds in the sample. Total soluble solids content (TSS) was determined by direct readout using a digital refractometer. Total titratable acidity (TTA) as percentage of citric acid was determined by titration of 25 mL of juice with a solution of sodium hydroxide at 0.1 N (AOAC, 1990). The ratio of total soluble solids and total titratable acidity (TSS/TTA) was calculated. The technological index (TI), or quantity of soluble solids in the juice of a box of fruits weighting 40.8 kg (kg of TSS per box), was determined using the following equation: TI= (juice yield x soluble solids x 40.8) / 10,000, where TI= technological index; juice yield = WJ/WF × 100; soluble solids = soluble solids content; 40.8 kg = standard weight of a box of oranges (Giorgi et al., 1990). The industrial yield (IY) or number of boxes of oranges necessary to produce one metric ton (t) of frozen concentrate orange juice (66 °Brix frozen concentrated orange juice), was determined by the equation: IY=660/TI, where 660 is 660 kg of soluble solids contained in 1,000 kg of concentrated juice.

Estimates of planting density and yield

The theoretical planting density to establish new orchards was calculated using the equation proposed by Negri et al. (2005), in which the distance between rows and between trees in the row were obtained by adding 2.5 m to the canopy diameter and multiplying the canopy diameter by 0.75, respectively. The recommended row spacing was 2.5 m with 25% of canopy overlapping along the row (Negri et al., 2005). Fruit yield (t ha^{-1}) and number of boxes ha^{-1} produced were also estimated.

Experimental design and data analysis

The experimental design was fully randomized, with thirteen treatments, five replications and one tree per plot. The data were subjected to analysis of variance and the means were compared by the Scott-Knott test at 5% probability, using the SAS software (SAS Institute, 2001).

RESULTS

Tree vigor

Pera Seleção 27 had the largest tree vigor based on tree height, and canopy diameter and volume among all the clones and selections of Pera sweet orange included in the study (Table 1). In contrast, Pera D-6 was the only one that had the lowest values for all three vigor variables. In addition, Seleção 11, Seleção 14, and IPR 153 clones also had the small canopy volume (Table 1).

Yield and yield efficiency

The clones IPR 159, Morretes, Seleção 12 and Seleção 27 were the most productives with average annual yield larger than 72.0 kg/tree for the period ranging from

2003 through 2006 (Table 2). Furthermore, Seleção 27 was the only one that had the largest yields every year, with average yield above 85.0 kg/tree/year and a peak of 138.5 kg/tree in 2006 (Table 2). Although Pera D-6 was among the ones with the lowest yields, it had the highest yield efficiency among all the clones for the period from 2003 through 2006, with 5.7 kg m^{-3} of canopy volume (Table 2). This yield efficiency of Pera D-6 is related to the small canopy volume of the tree (Table 1).

Table 1. Tree height, canopy diameter and volume of Pera sweet orange clones in Londrina, State of Paraná, Brazil, for the year of 2010

Clone	Tree height (m)	Canopy diameter (m)	Canopy volume (m^3)
IPR 153	3.1 c[1]	3.6 c	22.1 d
D-6	2.6 d	3.3 d	15.0 d
IPR 159	3.6 b	4.3 b	35.6 b
IPR 158	3.3 c	3.8 c	25.5 c
Morretes	3.4 c	4.1 b	31.1 c
Gullo	3.4 c	4.1 b	30.2 c
Vimusa	3.7 b	4.3 b	37.5 b
Seleção 12	3.7 b	4.1 b	33.8 b
Seleção 27	4.5 a	4.8 a	54.5 a
Seleção 11	3.2 c	3.7 c	23.2 d
Seleção 14	3.0 c	3.5 d	20.6 d
Seleção 15	3.2 c	3.9 c	27.6 c
Seleção 37	3.3 c	3.8 c	25.9 c
CV (%)	8.9	7.9	22.6

[1]Means followed by the same letter in the column did not differ according to the Scott-Knott test at 5% probability.

For the period from 2007 through 2010, Morretes, Gullo, Vimusa, Seleção 12 and Seleção 27 were the most productive clones, with annual yield higher than 94.0 kg/tree (Table 3). In addition, Seleção 27 again showed the highest yields in all years of evaluation, with fruit production above 129.0 kg/tree (Table 3). In the harvest of 2009, Seleção 27 produced more than 150.0 kg/tree (Table 3). The Morretes and Seleção 12 clones also had yields larger than 150.0 kg/tree in the harvest of 2008, but not differing statistically from Gullo, Vimusa and Seleção 27 (Table 3). The yield efficiency of the different Pera clones ranged from 3.8 to 5.1 kg m^{-3} of tree canopy (Table 3). The clone D-6 was the only one that had the highest yield efficiency for both periods of evaluation, with 5.1 kg m^{-3} of canopy volume, though Morretes, Gullo, Vimusa, Seleção 11, IPR 153, Seleção 14 and Seleção 12 were statistically similar (Table 3). In contrast, IPR 159, IPR 158 and Seleção 37 had the lowest yield efficiency, with values below 2.7 kg m^{-3} of tree canopy (Table 3). Some of these clones had average annual yields below 57.0 kg/tree (Table 3). On the other hand, the clone D-6 also

Table 2. Annual, cumulative and average yield and yield efficiency of Pera sweet orange clones in Londrina, State of Paraná, Brazil, for the harvest from 2003 through 2006

Clone	Yield per tree (kg)						Yield efficiency (kg m^{-3})
	Year				Cumulative	Average	
	2003	2004	2005	2006	(2003-2006)	(2003-2006)	
IPR 153	15.7 b[1]	58.6 b	18.9 c	72.9 c	166.2 c	41.6 c	4.5 b
D-6	29.4 a	41.2 b	25.8 c	63.5 c	160.0 c	40.0 c	5.7 a
IPR 159	38.0 a	102.7 a	48.7 b	99.2 c	288.7 a	72.2 a	4.0 c
IPR 158	30.6 a	74.9 a	42.8 b	83.7 c	232.0 b	58.0 b	3.8 c
Morretes	33.7 a	83.3 a	55.5 b	118.7 b	290.7 a	72.7 a	5.0 b
Gullo	37.0 a	55.5 b	51.7 b	96.2 c	240.3 b	60.1 b	4.7 b
Vimusa	18.7 b	70.3 b	52.7 b	112.3 b	254.0 b	63.5 b	3.9 c
Seleção 12	16.9 b	84.0 a	55.1 b	147.2 a	303.3 a	75.8 a	4.2 c
Seleção 27	30.8 a	92.7 a	80.2 a	138.5 a	342.3 a	85.6 a	3.5 c
Seleção 11	7.9 b	65.8 b	20.3 c	83.8 c	177.8 c	44.4 c	4.1 c
Seleção 14	15.1 b	46.8 b	22.2 c	70.2 c	154.3 c	38.6 c	3.7 c
Seleção 15	21.6 b	59.7 b	25.7 c	106.2 b	213.1 c	53.3 c	3.6 c
Seleção 37	25.9 a	48.2 b	32.6 c	80.0 c	186.7 c	46.7 c	2.8 d
CV (%)	45.3	33.9	29.6	21.8	20.0	20.0	13.1

[1]Means followed by the same letter in the column did not differ according to the Scott-Knott test at 5% probability.

Table 3. Annual, cumulative and average yield, and yield efficiency of Pera sweet orange clones in Londrina, State of Paraná, Brazil, for the harvests from 2007 through 2010

Clone	Yield per tree (kg)						Yield efficiency
	Year				Cumulative	Average	
	2007	2008	2009	2010	(2007-2010)	(2007-2010)	($kg\ m^{-3}$)
IPR 153	52.2 c[1]	100.6 b	84.9 c	44.7 c	282.4 b	70.6 b	4.5 a
D-6	49.8 c	81.6 c	63.0 c	32.7 c	227.2 b	56.8 b	5.1 a
IPR 159	72.5 c	119.2 b	59.4 c	29.8 c	280.9 b	70.2 b	2.6 c
IPR 158	60.0 c	74.8 c	57.3 c	33.3 c	225.4 b	56.3 b	2.7 c
Morretes	90.6 b	173.2 a	94.3 b	82.7 b	440.8 a	110.2 a	5.0 a
Gullo	56.1 c	146.0 a	106.8 b	69.0 b	378.0 a	94.5 a	4.6 a
Vimusa	102.2 b	144.6 a	130.1 a	71.6 b	448.5 a	112.1 a	4.6 a
Seleção 12	112.2 b	157.2 a	102.5 b	58.7 c	430.6 a	107.6 a	4.3 a
Seleção 27	135.3 a	127.3 a	151.6 a	103.1 a	517.4 a	129.3 a	3.5 b
Seleção 11	58.5 c	108.3 b	107.5 b	50.2 c	324.5 b	81.1 b	4.5 a
Seleção 14	35.8 c	111.5 b	63.0 c	36.8 c	247.2 b	61.8 b	3.8 a
Seleção 15	66.3 c	144.2 a	66.8 c	45.1 c	322.4 b	80.6 b	3.7 b
Seleção 37	57.8 c	67.7 c	46.9 c	41.4 c	213.7 b	53.4 b	2.4 c
CV (%)	33.0	24.0	32.5	38.9	22.1	22.1	16.2

[1]Means followed by the same letter in the column did not differ according to the Scott-Knott test at 5% probability.

had an average annual yield below 57.0 kg/tree, but due to the small tree size it had the highest yield efficiency among all clones evaluated (Table 3).

The clones of Pera with the highest cumulative yields from 2003 through 2010 were Seleção 27, Seleção 12 and Morretes. The annual yield for these clones was higher than 87.0 kg/tree (Tables 2 and 3). Seleção 27 was the most productive, with cumulative yield of 859.7 kg/tree over eight harvests, with an annual yield averaging 91.7 kg/tree for the entire period. In contrast, the clones currently recommended for planting in the State of Paraná, IPR 158 and IPR 159, had cumulative yield below 570.0 kg/tree, for the same eight harvests, with an annual average yield lower than 72.2 kg/tree (Tables 2 and 3).

Fruit characteristics

Fruit mass, height and diameter ranged from 123.7 to 160.9 g, 6.6 to 7.4 cm and 6.3 to 6.9 cm, respectively, for the 13 clones of Pera included in the study (Table 4). Higher values for fruit size were observed for IPR 153, Morretes, Gullo, Vimusa, Seleção 12, Seleção 27 and Seleção 11 (Table 4). These seven clones produced fruits with an average weight of over 147.0 g (Table 4). In contrast, the smallest fruit size was observed for the clones D-6, IPR 159, IPR 158, Seleção 14 and Seleção 15 (Table 4).

Based on the diameter of the fruits, the clones could be classified as follows (CEAGESP, 2000): caliper 68 for IPR 153, Morretes, Gullo, Vimusa and Seleção 12; caliper 66 for Seleção 27 and Seleção 11, and caliper 63 for D-6, IPR 159, IPR 158, Seleção 14, Seleção 15 and Seleção 37.

The number of seeds ranged from 3.4 to 4.8 per fruit and the highest number of seeds was observed for the clones D-6, IPR 159, IPR 158, Morretes, Gullo, Seleção 27, Seleção 11, and Seleção 37, differing from the other five clones (Table 4).

In terms of juice quality, the clones D-6, IPR 159, IPR 158, Gullo, Seleção 14, Seleção 15 and Seleção 37 had the highest values for total soluble solids (TSS) content, ranging from 11.50 to 12.38 ^{o}Brix and differing from the other clones (Table 5). The highest level of total titratable acidity (TTA) was 1.16% for the fruits of Pera D-6, also differing from the other clones, in contrast to the values of 0.80% and 0.77% determined for Vimusa and Seleção 27, respectively (Table 5).

The Pera clones could be grouped in four categories based on the TSS/TTA ratio (Table 5). Seleção 37 and IPR 158 had the highest values for TSS/TTA ratio, with ratio above 13.5 (Table 5). In contrast, D-6, Seleção 12 and Seleção 15 had the lowest values, with ratios below 11.59 (Table 5).

Table 4. Fruit mass, height and diameter, and number of seeds per fruit of Pera sweet orange clones in Londrina, State of Paraná, Brazil, based on data of the harvests from 2006 through 2010

Clone	Fruit mass (g)	Fruit height (cm)	Fruit diameter (cm)	Number of seeds per fruit
IPR 153	147.9 a[1]	7.2 a	6.8 a	3.4 b
D-6	123.7 c	6.6 b	6.3 b	4.8 a
IPR 159	132.6 c	6.9 b	6.4 b	4.4 a
IPR 158	155.0 a	6.7 b	6.3 b	4.2 a
Morretes	157.5 a	7.4 a	6.9 a	4.4 a
Gullo	153.2 a	7.1 a	6.8 a	4.2 a
Vimusa	160.3 a	7.3 a	6.8 a	3.6 b
Seleção 12	158.6 a	7.4 a	6.9 a	3.8 b
Seleção 27	148.7 a	7.2 a	6.7 a	4.6 a
Seleção 11	150.7 a	7.3 a	6.6 a	4.4 a
Seleção 14	130.8 c	6.8 b	6.4 b	4.0 b
Seleção 15	138.3 b	6.9 b	6.5 b	3.8 b
Seleção 37	141.5 b	7.0 a	6.4 b	4.2 a
CV (%)	6.5	3.9	3.8	13.4

[1]Means followed by the same letter in the column did not differ according to the Scott-Knott test at 5% probability.

Table 5. Total soluble solids (TSS), total titratable acidity (TTA), TSS/TTA ratio, juice yield, technological index and industrial yield of clones of Pera sweet orange in Londrina, State of Paraná, Brazil, based on data of the harvests from 2006 through 2010

Clone	TSS (ºBrix)	TTA (%)	TSS/TTA ratio	Juice yield (%)	Technological index (kg TSS/box)	Industrial yield (boxes/MT)
IPR 153	10.90 b[1]	0.86 c	12.71 b	50.8 b	2.2 d	295.3 b
D-6	12.38 a	1.16 a	10.91 d	53.7 a	2.7 a	245.9 d
IPR 159	11.78 a	0.90 c	13.22 b	53.3 a	2.6 b	259.8 d
IPR 158	11.97 a	0.90 c	13.52 a	51.5 b	2.5 b	265.3 d
Morretes	10.60 b	0.87 c	12.27 c	54.5 a	2.4 c	284.3 c
Gullo	11.50 a	0.94 c	12.24 c	54.3 a	2.5 b	261.6 d
Vimusa	10.12 c	0.80 d	12.78 b	53.3 a	2.2 d	302.8 b
Seleção 12	10.25 c	0.88 c	11.59 d	49.7 b	2.1 e	332.8 a
Seleção 27	9.52 c	0.77 d	12.42 c	51.2 b	2.0 e	336.8 a
Seleção 11	10.94 b	0.90 c	12.20 c	52.5 a	2.3 c	284.1 c
Seleção 14	12.18 a	1.03 b	11.86 c	50.3 b	2.5 b	267.2 d
Seleção 15	11.64 a	1.05 b	11.54 d	51.2 b	2.4 c	273.4 c
Seleção 37	11.92 a	0.87 c	13.92 a	51.5 b	2.5 b	265.3 d
CV (%)	5.4	6.9	4.5	2.0	5.3	6.1

[1]Means followed by the same letter in the column did not differ according to the Scott-Knott test at 5% probability.

Juice content ranged from 49.7% to 54.5%, with D-6, IPR 159, Morretes, Gullo, Vimusa and Seleção 11 showing the highest values (Table 5). The other seven clones of Pera had juice content above 52.0% (Table 5).

The best technological index, which has important industrial implications, was obtained for Pera D-6 clone, with 2.7 kg of total soluble solids per box of fruit (Table 5). The industrial yield, that indicates the number of boxes of 40.8 kg of oranges required to produce one ton of frozen concentrated orange juice ranged from 245,9 to 267,2 boxes for the best ones and was provided by Pera D-6 with 245.9 boxes (Table 5). However, the clones IPR 159, IPR 158, Gullo, Seleção 14 and Seleção 37 were similar. In contrast, Seleção 12 and Seleção 27,

Table 6. Estimates for row and tree spacing, number of trees ha^{-1}, yield (t) ha^{-1} and yield as number of boxes (40.8 kg) of fruit ha^{-1}, based on canopy diameter, for clones of Pera sweet orange

Clone	Spacing		Number of	Yield	Number of boxes
	row (m)	tree (m)	trees ha^{-1}	(t ha^{-1})	(boxes ha^{-1})
IPR 153	6.1 c[1]	2.7 c	602.1 b	42.1 b	1.032.1 b
D-6	5.8 d	2.4 d	714.5 a	39.5 c	968.9 c
IPR 159	6.8 b	3.2 b	454.8 c	31.8 c	778.9 d
IPR 158	6.3 c	2.9 c	555.6 b	31.2 c	765.2 d
Morretes	6.6 b	3.1 b	497.4 c	54.4 a	1.332.2 a
Gullo	6.6 b	3.1 b	495.6 c	46.4 b	1.138.0 b
Vimusa	6.8 b	3.3 b	448.9 c	50.5 a	1.237.4 a
Seleção 12	6.6 b	3.1 b	497.2 c	51.3 a	1.257.8 a
Seleção 27	7.3 a	3.6 a	388.4 c	49.1 a	1.203.6 a
Seleção 11	6.2 c	2.8 c	573.7 b	46.2 b	1.133.0 b
Seleção 14	6.0 d	2.6 d	641.8 a	37.8 c	925.8 c
Seleção 15	6.4 c	2.9 c	533.6 c	42.2 b	1.034.9 b
Seleção 37	6.3 c	2.9 c	550.9 b	29.5 c	722.1 d
CV (%)	4.8	7.9	13.6	15.5	15.5

[1]Means followed by the same letter in the column did not differ according to the Scott-Knott test at 5% probability.

which were highly productive, had the lowest industrial yields, with over 330 boxes required to produce one ton of frozen concentrated orange juice (Table 5).

Theoretical planting density and yield estimates

Based on the citrus orchard planning studies (Negri et al., 2005), Seleção 27 had the highest estimates for row distance with 7.3 m, and for tree spacing with 3.6 m (Table 6). In contrast, the clones D-6 and Seleção 14 had the lowest estimates for these two parameters (Table 6). The number of trees per hectare estimated for the clones of Pera ranged from the lowest 388.4 trees ha^{-1} for Seleção 27 to the highest 714.5 trees ha^{-1} for D-6 clone (Table 6). In regard to yield, the estimated yields were above 1,200 boxes of 40.8 kg ha^{-1} for Morretes, Vimusa, Seleção 12 and Seleção 27 (Table 6).

DISCUSSION

Sweet orange [*Citrus sinensis* (L.) Osbeck] is the most important citrus species around the world. In Brazil, sweet oranges have particularly environmental conditions for high yield and superior fruit quality for fresh market and industrial processing. Pera sweet orange is the most important citrus cultivar in Brazil (Carvalho et al., 2015; Salibe et al., 2002), however, there is a need to identify the best clones of Pera for each region as one clone may not perform well everywhere (Carvalho et al., 2015; Domingues et al., 1999, 2004; Donadio et al., 1995; Donadio, 1999; Figueiredo, 1991; Salibe et al., 2002; Stuchi et al., 2004; Tazima et al., 2010).

The tree height ranged from 2.6 up to 4.5 m (Table 1), being classified as dwarf (2.4 m) to semi-dwarf (3.6 m) according to Bitters et al. (1979). Fifteen years old trees of Pera Bianchi and Pera Vimusa grafted on Rangpur lime had height of 3.4 m and 3.5 m, respectively, in a study carried out in Cordeirópolis, SP, Brazil (Domingues et al., 2004). The small size of the citrus tree is agronomically interesting, because may allow to increase the efficiency of phytosanitary treatments and to reduce harvesting costs. In addition, small tree size also turns possible to increase tree density, and consequently the yield per area (Pompeu Junior, 2001).

Some clones of Pera were highly productive and produced more than 2.0 and 3.0 boxes of 40.8 kg per tree in the first four and last four harvests, respectively, as Seleção 27 (Tables 2 and 3). In the State of São Paulo, Brazil, the productivity ranged from 1.7 to 1.92 box of fruits per tree for the harvests of 2011 and 2012 (CONAB, 2012). Furthermore, the clones Morretes, Gullo, Vimusa, Seleção 12 and Seleção 27 were much more productive than clones under recommendation for the State of Paraná, Brazil, such as IPR 158 and IPR 159 (Table 3).

Regarding to fruit mass, the weight ranged from 123.7 to 160.3 g for the clones D-6 and Vimusa (Table 4). However, most of the clones produced fruits larger than those obtained in other studies on Pera sweet orange, where the average mass was 145.0 g (Figueiredo, 1991). In studies carried out in Cordeirópolis, State of São Paulo, Brazil, the average fruit mass was 132.3 g for Vimusa, 135.5 g for Gullo and 136.5 g for Bianchi (Domingues et al., 1999). In contrast, average fruit mass ranged from 149.8 to 159.6 g for Pera Vacinada 4 (I-59), Pera Bianchi (I-89) and Pera Vacinada 3 (I-58) in studies carried out in the State of Paraná, Brazil (Tazima et al., 2010). Furthermore, fruit size in sweet oranges may be related not only to genetic characteristics of each cultivar, but can be affected by environmental conditions, mineral nutrition and virus infection (Salibe et al., 2002; Silva & Donadio, 1998). Tristeza virus strain that infects the citrus tree plays an important role in tree yield and fruit size, particularly for Pera that is more sensitive to this virus as compared to other sweet orange cultivars (Domingues et al., 1999, 2004; Donadio et al., 1995; Donadio, 1999; Figueiredo, 1991; Giampani et al., 2016; Salibe et al., 2002; Silva & Donadio, 1998).

The number of seeds observed in this study is similar to those reported by Figueiredo (1991), ranging from three to four seeds per fruit for the different clones of Pera (Table 4). These results are quite different from the eight seeds per fruit obtained in other study for this same sweet orange cultivar (Malerbo-Souza et al., 2003). We should point out that the number of seeds in citrus fruits can be dependent on the environmental conditions, physiological age of the plant, infection by systemic pathogens and cultural practices (Machado et al., 2005). The fruits which flowers were pollinated by bees were heavier and had a greater number of seeds (Malerbo-Souza et al., 2003).

Total soluble solids (TSS) contents obtained in other studies for Vimusa, Gullo and Bianchi clones were 12.8, 13.4 and 12.9 °Brix, respectively (Domingues et al., 1999). These values were higher than the range of 11.5 to 12.4 °Brix observed in this study (Table 4). However, variations in soluble solids content for the Pera clone have also been reported by Stuchi et al. (2004). These differences could be due to climatic conditions and the maturity stage of the fruit at harvest (Viégas, 1991).

Total titratable acidity (TTA) values of 0.80% and 0.77%, for Vimusa and Seleção 27, respectively, were lower than those determined for other clones of Pera (Table 4), but these values were close to the 0.95% reported for Pera sweet orange (Figueiredo, 1991). Titratable acidity above 1.05 has been reported for Pera Vacinada 3 (I-58) and Pera Vacinada 4 (I-59) (Tazima et al., 2010), and also for the clones Vimusa, Bianchi, and Gullo (Domingues et al., 1999). Titratable acidity value depends largely on the time of fruit sampling for analysis. Further, sweet orange with higher acidity values are normally common for late maturing sweet orange cultivars (Domingues et al., 1999).

The TSS/TTA ratio of 12.5 is usually characteristic for Pera sweet orange (Figueiredo, 1991). However, values close to 10.9, obtained for D-6 have also been reported for different clones of Pera, such as Pera Premunizada 1212, Vimusa, Bianchi, and Gullo (Domingues et al., 1999). For industrial purpose, the ideal ratio for orange juice production is between 11 and 14 (Petto Neto & Pompeu Junior, 1991). In this range, the acidity is still adequate for maintaining the quality of the juice after fruit processing (Viégas, 1991). In this study, all Pera clones had a ratio above 11, with the exception of D-6 (Table 5).

The juice content ranged from 49.7 to 54.5% (Table 5), which is close to the value expected for Pera sweet orange, that is 52.0% (Figueiredo, 1991). However, variations in juice content, ranging from 47.6 to 63.2%, have also been reported for Pera sweet orange (Domingues et al., 1999; Stuchi et al., 2004).

Regarding the technological index, the value of 2.7 kg for total soluble solids per box (Table 5) is above the average of 2.5 kg of total soluble solids per box that has been reported for Pera (Figueiredo, 1991). Despite the high yield and large fruit size, the Seleção 12 and Seleção 27 clones had the lowest technological index (Table 5). Further, the industrial yields were above 330 boxes t^{-1} of frozen concentrate orange juice (FCOJ) for these two clones of Pera (Table 5). These values are much higher than 257 boxes t^{-1} obtained in some regions of the States of São Paulo and Minas Gerais, and the 264 boxes t^{-1} observed for the States of Bahia, Sergipe, Paraná and Rio Grande do Sul, Brazil (Neves et al., 2010). Nevertheless, several others clones of Pera had industrial yields below 300 boxes t^{-1} (Table 5).

Planning of orchard densities and yield estimates for the different Pera clones indicated potential yields higher than 1,200 boxes ha^{-1} (Table 6). Theoretically, these included the clones Morretes (I-34), Seleção 12, Vimusa and Seleção 27, with both potential yields of 1,332, 1,258, 1,237 and 1,204 boxes ha^{-1}, respectively (Table 6) and compensating the lower technological index (Table 5). Thus, the potential yield for these clones of Pera is much higher than the ones obtained for clones IPR 158 and IPR 159 (Table 6).

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