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Phenology, yield and fruit quality of four persimmon (*Diospyros kaki* L.) cultivars in São Paulo's Midwest countryside, Brazil

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The aim of this study is to evaluate the phenology, yield and fruit physicochemical characteristics of four persimmon cultivars (*Diospyros kaki* L.) in São Paulo's Midwest countryside, Brazil. The persimmon cultivars studied were 'Pomelo', 'Rama Forte', 'Fuyu' and 'Rubi'. The main phenological phases of persimmons trees were evaluated. Despite significant differences between cultivars in the early and intermediate stages of the plants development such as branch development, full blossom and fruiting's onset, the time required between the fruit's pruning and harvesting was similar among the cultivars. It could be observed that only 'Pomelo' persimmon trees presented male flowers. However on 'Rubi', 'Fuyu' and 'Rama Forte' persimmons trees were found the largest number of female flowers, fruits fixation index and number of fruits per branch. Nevertheless, there were no differences among the cultivars regarding productivity, which could be due to the persimmon fruits physical characteristics. The fruits' diameter growth behavior was evaluated and it was observed that all cases were defined as double sigmoidal, defined by three single phases. Regarding the chemical characteristics, there were no differences among the cultivars' pH and soluble solids content; however, in general, the 'Pomelo' persimmon fruit presented less titratable acidity and a higher maturation index rating.

Key words: Fruit growth, fruit set, flowering, double sigmoid, maturity.

INTRODUCTION

Persimmon cropping (*Diospyrus kaki* L.) has grown in importance over the last years in Brazil, both in terms of acreage and consequently, production's increase, which has raised the amount of fruits offered to the domestic market. Thus, for this reason, growers have been encouraged to export part of their harvest (Silva et al.,

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2011)

Brazil is the fourth highest producer in the world's persimmon production ranking, whilst China is the biggest one, followed by Japan and South Korea. Brazil's South and Southeast regions are the largest producers, led by the state of São Paulo (Silva et al., 2011). In this state particularly, the main producer towns in 2015, were Mogi das Cruzes, Campinas and Sorocaba with 49.9; 19.5 and 17.8 thousand tons of fruit, respectively, while Botucatu, in São Paulo's Midwest countryside, produced only 208 tons in the same year (IEA, 2016). The main varieties produced and sold within Brazilian domestic market are, primarily 'Rama Forte', 'Giombo' and 'Fuyu' fruits, despite pomological characteristics and other varieties' production, such as 'Pomelo' and 'Fuyuhana' (Pereira and Kavati, 2011). What could be observed was that even though the culture has established itself and several of its centers of production, as well as variety with high production and commercial potential, it is possible to notice that technological evolution for persimmon's culture and plantation remains stagnant. Probably, the little commercial interest the culture kept for a long time and the easy production, due to the roughness and high yield of the crops, have been some of the factors responsible for slowing down studies that seek new culture technologies developed for the crop (Pereira and Kavati, 2011).

In order to meet quality demanded standards from the consumer market, there is a need to expand the research field for knowledge regarding persimmon cropping, including aspects ranging from nutrition, irrigation and plants' canopy handling to before and after harvest studies (Biasi et al., 2007; Souza et al., 2011; Vieira et al., 2016), considering that these factors might be affected by growing's location and chosen crop. The fruit farm, for instance, when led according to different growth stages, allows strategies and decisions to be defined beforehand, which contributes to improving the crops' efficiency and yield (Corsato et al., 2005).

Therefore, studies on phenological persimmon characteristics are also essential, since they allow the creation of growth models describing and planning in advance the crop's growth in each region. Besides, it is also essential to evaluate physical and chemical qualities of the fruit, whereas persimmon is consumed mainly in its natural form and the sugar and acid contents as well as their (sugar/acid) contrast relationship contribute greatly to the fruit's sensorial attributes (Veberic et al., 2010).

Considering these contexts, the aim of this study was to evaluate the phenology, yield and fruit physicochemical characteristics of four persimmon cultivars in São Paulo's Midwest countryside, Brazil.

MATERIALS AND METHODS

Experimental site, plants' growing condition and handling

This study was carried out inside persimmon fruit orchard located in Botucatu, in the state of São Paulo, Brazil's southeast (22° 55' 55" S, 48° 26' 22" W, 810 m above the sea), from July 2013 to January 2014. According to the Köppen classification, the climate is type *Cwa*, that is, a subtropical weather with an average temperature at 20.7°C, and a rainfall yearly average rate of 1359 mm, of which most of the rain season occurs during the summer months (CEPAGRI, 2016). The soil of the area was classified as UDULT according to the Brazilian company Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA, 2006).

The experimental procedures consisted of four persimmon cultivars: 'Pomelo' (IAC 6-22), 'Rama Forte', 'Fuyu' and 'Ruby' (IAC 8-4), all of them grafted on the 'Pomelo' rootstock. The persimmon trees were 4 year-old crops, and they were arranged in 3 x 3 m seeding spots inside an orchard without irrigation system. The annual winter pruning was performed July 13th 2013, when the trees were in their dormancy period and before early budding. During the pruning, dry, diseased, broken and weak darkened branches were removed.

Measurements

Phenological stages of persimmon plants

After budding starts, according to García-Carbonell et al. (2002), with slight differences, were assessed the following phenological stages: branch development and closed flower buds– visible but still jointed sepals; bud opening start– the parting of the sepals; full bloom– when 50% of the flowers reach anthesis; the onset of fruiting– when most petals fall down; the start of the physiologic fruit drop; fruits known as "chumbinho"– when the fruits reach about 20% of their normal size; these fruits start losing their green color; the maturation and harvesting. The assessments were performed weekly and the phenological stages lengths were expressed as days after pruning (DAP).

Flowering, fruit's set and growth development

In the beginning of anthesis, the number of female (FF) and male flowers in 10 productive established branches were determined in each branch, in the early stages of maturation, with all this data, the number of fixed fruits (NFF) were counted to determine fixation index fruits (FIF), using the formula proposed by Corrêa et al. (2002): FIF = [(NFF/FF) 100]. Afterwards, 10 fruits were selected per experimental trials and measured weekly with a digital caliper. The transverse diameter of the fruits produced a growth curve.

Yield

The yield per plant (kg) and productivity (t ha^{-1}) were estimated based on the number of fruits per tree and their mass. Harvesting was performed when fruits reached their physiological maturation, showing firm pulp.

Physicochemical fruits characteristics

In order to eliminate tannin, the fruits were exposed to volatilized ethyl alcohol for 48 h (contents: 70 ml alcohol to 12 kg fruit). Then, they were kept under environmental condition (17 ± 2°C) until full maturation. After that, a physicochemical analysis of 10 chosen fruits per experimental trial was performed.

The physical characteristics of the persimmon fruits were evaluated by determinations of their mass (g), length (cm) and width (cm). The chemical characteristics were assessed according to determinations of soluble solids content (°Brix), titratable acidity

Table 1. Phenological stages of the different persimmon cultivars grown in São Paulo's Midwest countryside, Brazil. Botucatu-SP, 2014.

Phenological stages (DAP)[1]	Pomelo	Rama Forte	Fuyu	Rubi
Branch development and closed flower bud	41.3 ± 0.5^{a}	48.8 ± 6.5^{a}	64.5 ± 4.4^{b}	58.0 ± 0.0^{b}
Start of bud opening	52.0 ± 0.0^{a}	62.0 ± 6.7^{b}	73.0 ± 5.7^{c}	69.5 ± 2.9^{bc}
Full bloom	58.0 ± 0.0^{a}	68.0 ± 7.1^{b}	84.5 ± 5.0^{c}	76.5 ± 2.9^{bc}
Onset of fruiting	66.0 ± 0.0^{a}	74.8 ± 6.7^{a}	95.3 ± 5.5^{b}	89.0 ± 7.3^{b}
Physiologic drop fruits	73.0 ± 0.0^{a}	83.5 ± 7.0^{ab}	106.3 ± 9.9^{c}	96.5 ± 3.7^{bc}
Fruits about 20% of its final size	80.0 ± 0.0^{a}	94.3 ± 9.6^{ab}	113.5 ± 11^{c}	103.0 ± 4.1^{bc}
Fruits start losing its green color	211.3 ± 0.5^{a}	229.0 ± 12^{bc}	218.8 ± 5.7^{ab}	240.0 ± 0.0^{c}
Maturation and harvesting	266.3 ± 3.8^{a}	287.3 ± 17^{a}	265.8 ± 13^{a}	271.5 ± 6.1^{a}

Means values ± standard deviation (n = 4) followed by different letters in the same row differ significantly (Tukey test, $p < 0.05$). [1]DAP: Days after pruning.

(percent of malic acid), pH and maturation index. In order to obtain these chemical characteristics, the fruits were mashed in a mixer device until they became a homogenized pulp. The titratable acidity was obtained using titration with 0.1 N standardized hydroxide sodium solution with phenolphthalein as the indicator.

Experimental design and statistical analyses

In order to determine the growth curve, a completely randomized design with split plots of four replicates and 10 fruit per repetition was designed. Each plot represented different persimmon cultivars, and subplots were different evaluation times (days after pruning). For other characteristics assessment, a completely randomized design with four handlings and four replicates was set.

All data were analyzed by ANOVA applying the Tukey test, significance of 5% on plots and regression analysis on subplots. The models were chosen based on the coefficient of significance determination ($R^2 \geq 0.70$). For other variables, the data were subjected to ANOVA comparison through the Tukey test at significance of 5%. All analysis was run using the statistical software package SISVAR (Ferreira, 2011). The Pearson's correlation (r) analysis was also conducted (with 5 and 1% probability) to investigate the relation within all characteristics evaluated, aided by the statistical software package ASSISTAT (Silva and Azevedo, 2002).

RESULTS AND DISCUSSION

Phenological stages of persimmon plants

'Rubi' and 'Fuyu' persimmon cultivars took more time to reach closed flower buds and branch development stages, it was possible to notice that the petals remained closed until 58 and 64 days after pruning (DAP), respectively, differently from 'Pomelo' and 'Rama Forte' crops, which reached the same stage in 41 and 59 DAP, respectively (Table 1). Although the needed days to observe closed flower buds is similar in all those sorts of crops, the 'Pomelo' cultivar required a shorter time to start closed flower bud opening and then reach its full bloom, this stage was achieved in 52 and 58 DAP, differing from the other sorts of crops.

A study developed in Eldorado do Sul (Rio Grande do Sul, Brazil) with persimmon trees, obtained the same result from 'Pomelo' and 'Rama Forte' crops, which required 50 days to reach full bloom stage, while 'Fuyu' crops needed 62 days (Campos et al., 2015), corroborating the current study results. The precocity of 'Pomelo' and 'Rama Forte' cultivars, and late characteristics of the 'Fuyu' ones, especially in the intermediate phenological stage, seems to be an intrinsic characteristic of these sorts of crops.

The beginning of fruiting in 'Pomelo' and 'Rama Forte' cultivars occurred in 66 and 75 DAP, respectively; with significant differences from the 'Ruby', which reached the same stage on an average of 92 DAP. The 'Ruby' and 'Fuyu' varieties took more days to reach the beginning of physiological fruit drop, which occurred in 96 and 106 DAP, respectively, regarding the "chumbinho" phenological stage, it was observed in 103 and 113 DAP, respectively.

The full bloom period and physiological fruit drop was in average 15 days to 'Pomelo' and 'Rama Forte', and 21 days to 'Fuyu' and 'Rubi' cultivars. The first peak of fruit drop occurred between 20 and 30 days after flowering. This phenological phase occurs when roots and branches of persimmon tree reach their lowest levels of their carbohydrate reserves and simultaneously compete with fruits (George et al., 1997).

The biggest break among phenological phases occurred between the "chumbinho" fruit stage and when fruits start losing their green color, it happened in 105, 131, 135 and 137 days in 'Fuyu', 'Pomelo', 'Rama Forte' and 'Rubi' cultivars, respectively. Due to this small gap observed in 'Fuyu' persimmon tree, the time required to start losing its green color was similar to 'Pomelo', it took 219 and 211 DAP, respectively.

'Rama Forte' and 'Fuyu' cultivars required longer periods to start losing color, around 235 DAP. However, the period in between when fruits started losing their green color and harvesting was only 31 days long for 'Rubi', while 'Rama Forte', 'Pomelo' and 'Fuyu' reached

Table 2. Number of flowers and fruits per branch and fixations index fruits of the different persimmon cultivars grown in São Paulo's Midwest countryside, Brazil (Botucatu-SP, 2014).

Cultivar	Female flowers per branch	Male flowers per branch	Fruits per branch	Fixation index fruits[2] (%)
Pomelo	2.67 ± 0.68[b]	2.44 ± 0.61	1.67 ± 0.47[b]	54.88 ± 17[b]
Rama Forte	3.56 ± 0.14[ab]	no[1]	2.89 ± 0.67[ab]	83.89 ± 13[a]
Fuyu	3.62 ± 0.79[ab]	no	3.00 ± 0.91[a]	69.12 ± 9.9[ab]
Rubi	4.17 ± 0.11[a]	no	2.12 ± 0.14[ab]	64.32 ± 2.2[ab]

Means values ± standard deviation (n = 4) followed by different letters in the same column differ significantly (Tukey test, $p < 0.05$). [1]no: not observed. [2]It was determined using the following formula: Fruits fixation index = [(number of fixed fruits/number of female flowers) 100].

58, 53 and 47 DAP, respectively. Thus, there were no significant differences for all persimmon cultivars on the maturation and harvesting stages, which occurred, in average, in 273 DAP. The same result was obtained by Campos (2014), in Rio das Antas (Rio Grande do Sul, Brazil), where 'Pomelo' and 'Rama Forte' cultivars were more precocious than other varieties, including 'Fuyu' persimmons in the intermediate stages, though all of them reached the final cycle at the same time.

Flowering, fruit's set and growth development

Considering the type of flower, only 'Pomelo' persimmon trees presented male flowers, an average of 2.4 flowers per branch (Table 2). The presence of male flowers in 'Pomelo' persimmon trees was expected. The flower biology of nine persimmon cultivars ('Costata', 'Fuyu', 'Kaoru', 'Mikado', 'Okira', 'Pomelo', 'Rama Forte', 'Regina' and 'Taubaté') was studied, and among them only 'Pomelo' and 'Mikado' presented flowers producing pollen (Campos et al., 2015). A breeding program developed by the Brazilian company Instituto Agronômico de Campinas (IAC, Brazil) aiming to undemanding varieties to cold proved the 'Pomelo' cultivar to be good male flower producers, ensuring self-pollination (Ojima et al., 1985). The possibility of self-pollination could ensure a higher fruit fixation index rating for 'Pomelo' cultivars; however, an average rating of approximately 55% could be noticed.

'Rubi', 'Fuyu' and 'Rama Forte' persimmon trees did not present male flowers, but in these cultivars, the largest number of female flowers were found at an order of 4.17, 3.62 and 3.56 female flowers per branch, respectively. This is an important characteristic, because it is directly correlated with the number of fruits per branch (r = 0.71, $p < 0.01$) and per plant (r = 0.66, $p < 0.01$), which will reflect the final yield.

Floral persimmon trees habits are very complex. Depending on the cultivar, the plants may be monoecious, dioecious or hermaphrodites (Campos et al., 2015). Most commercial cultivars are dioecious and bear only female flowers, as observed in this study. When there is no presence of staminate flowers, pollination can happen, persimmon trees may bear parthenocarpic fruits (García-Carbonell et al., 2002), which contributes to poor fruiting (Agustí, 2010). However, it was found that, even though there was no presence of male flowers, 'Rama Forte', 'Fuyu' and 'Ruby' cultivars had higher fruit fixation index ratings and number of fruits per branch. This is due to the presence of 'Pomelo' cultivars acting as a pollination source to the other cultivars. Keeping plants producing male flowers with viable pollen production is an alternative used in Brazil to increase fruiting and thus increasing productivity (Campos et al., 2015).

There was significant interaction between fruit diameter growth among the assessment days (Table 3). During growth stage, 'Pomelo' crops presented fruits larger in diameter; however, there was no difference as compared to 'Rama Forte' and 'Fuyu' cultivar in this study between 142 and 218 DAP. The 76 days period, that composed the interval between 142 and 218 DAP, were defined by low increase on fruit's diameter. The smallest fruit diameter throughout the evaluation period was observed for 'Rubi' cultivar, although, when the fruits reached the final growth stage, 'Rubi' did not present differences as compared to 'Rama Forte' and 'Fuyu' cultivars.

The growth behavior for all persimmon fruits was double sigmoidal (Figure 1), defined by three single phases. Phase I started when the fruits reached the phenological stage "chumbinho" and was characterized by a fast development promoted mainly by cells division. Afterwards, the fruit development gets into sigmoidal growth, which in turn becomes slower (Phase II). The final phase (Phase III) was determined by a period of exponential growth, when color changings and fruit ripening occur. As observed in this study, the same development behavior was noticed in 'Harbiye' persimmon crops, grown in Turkey (Candir et al., 2009).

Yield and physicochemical fruit characteristics

Despite the fact that no differences were observed in yield and productivity among cultivars, with an average of 12.09 kg plant^{-1} and 13.43 t ha^{-1}, respectively (Table 4), 'Rama Forte' produced more fruits (112.2 fruits per plant), approximately 93.4% higher than 'Pomelo' (58 fruits per

Table 3. Growth developments on transverse diameter (mm) of persimmon fruits from different cultivars grown in São Paulo's Midwest countryside, Brazil. Botucatu-SP, 2014.

DAP	Pomelo	Rama Forte	Fuyu	Ruby
101	30.35±1.7^{A}	21.09±6.7^{B}	18.56±2.6^{BC}	14.13±0.6^{C}
108	35.31±1.3^{A}	25.41±6.1^{B}	20.75±2.3^{BC}	17.99±0.7^{C}
115	39.37±2.4^{A}	29.33±5.9^{B}	25.94±1.6^{BC}	20.77±0.7^{C}
126	44.43±1.8^{A}	34.73±5.3^{B}	32.31±2.2^{BC}	27.09±0.7^{C}
134	48.34±1.8^{A}	38.30±4.5^{B}	37.24±3.7^{B}	30.27±0.5^{C}
142	49.33±2.2^{A}	43.69±5.7^{AB}	42.30±4.4^{BC}	36.43±1.5^{C}
149	51.53±2.3^{A}	44.09±5.4^{B}	44.97±4.2^{AB}	37.23±1.4^{C}
157	51.94±2.5^{A}	44.70±4.3^{BC}	47.75±4.6^{AB}	40.33±1.5^{C}
167	54.61±0.9^{A}	48.75±3.8^{A}	48.43±5.2^{A}	40.74±3.8^{B}
183	56.28±1.4^{A}	49.62±4.3^{AB}	51.85±5.3^{AB}	46.52±2.4^{B}
197	57.44±1.0^{A}	51.13±4.7^{AB}	52.93±6.5^{AB}	48.25±2.0^{B}
204	58.39±0.7^{A}	50.43±4.5^{B}	54.17±6.9^{AB}	49.74±2.2^{B}
212	58.91±1.0^{A}	50.84±4.3^{B}	54.20±7.1^{AB}	51.14±2.4^{B}
218	60.55±0.5^{A}	52.14±4.8^{B}	54.94±6.2^{AB}	51.43±2.2^{B}
224	64.30±2.0^{A}	52.70±5.3^{B}	55.90±5.6^{B}	52.80±2.1^{B}
240	68.34±1.4^{A}	55.15±6.6^{B}	58.87±4.0^{B}	55.41±2.0^{B}
244	69.76±0.5^{A}	57.34±8.0^{B}	60.78±4.7^{B}	57.71±1.4^{B}
251	70.49±1.5^{A}	58.32±6.8^{B}	61.90±5.8^{B}	58.88±1.5^{B}
259	71.40±0.8^{A}	60.42±6.4^{B}	61.93±5.5^{B}	59.60±0.8^{B}

Means values ± standard deviation (n = 4) followed by different letters in the same row differ significantly (Tukey test, p < 0.05).

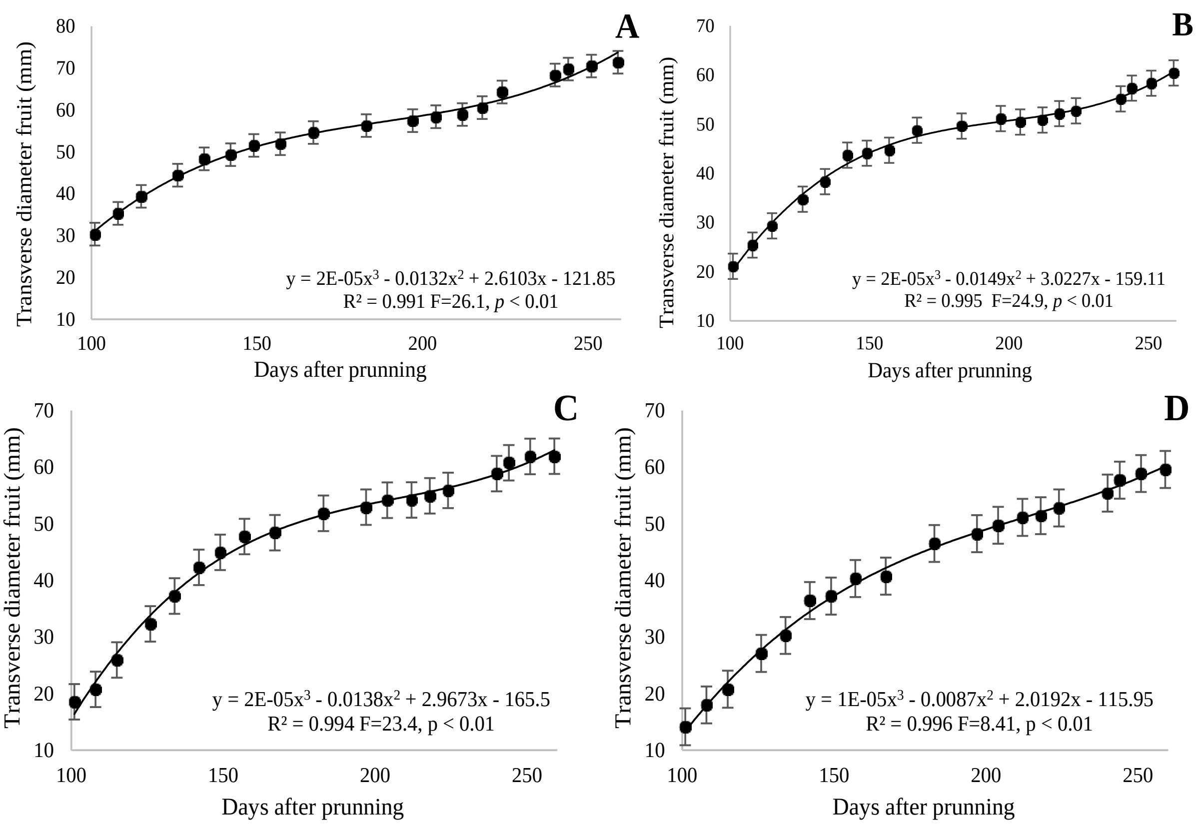

Figure 1. Evolution of persimmon fruits, 'Pomelo' (A), 'Rama Forte' (B), 'Fuyu' (C) and 'Rubi' (D) cultivars grown in São Paulo's Midwest countryside, Brazil, Botucatu-SP, 2014. Deviation lines indicate standard deviation from four replicates, with 10 persimmon fruits each.

Table 4. Yield and physicochemical characteristics of persimmon fruits from different cultivars grown in São Paulo's Midwest countryside, Brazil. Botucatu-SP, 2014.

Cultivar	Yield per plant (kg)	Productivity (t ha^{-1})	Fruits per plant	Fresh fruit mass (g)	Length fruit (mm)
Pomelo	13.93±4.41^{a}	15.48±4.89^{a}	58.00±15.7^{b}	230.9±13.6^{a}	65.50±1.02^{a}
Rama Forte	12.30±4.26^{a}	13.67±4.65^{a}	112.2±20.1^{a}	103.0±29.8^{c}	48.27±8.94^{b}
Fuyu	13.31±2.01^{a}	14.78±2.23^{a}	87.00±10.7^{ab}	150.7±26.1^{b}	62.44±9.18^{a}
Rubi	8.81±2.29^{a}	9.79±2.54^{a}	74.13±7.69^{b}	114.4±18.2^{c}	49.42±5.13^{b}
Cultivar	**Width fruit (mm)**	**pH**	**Soluble solids (°Brix)**	**Titratable acidity (%)**	**Maturation index**
Pomelo	75.22±1.08^{a}	5.36±0.04^{a}	20.23±0.40^{a}	0.11±0.01^{b}	181.8±19^{a}
Rama Forte	60.88±5.64^{c}	5.51±0.11^{a}	19.92±2.72^{a}	0.14±0.03^{a}	147.5±31^{b}
Fuyu	67.57±4.01^{b}	5.33±0.08^{a}	20.96±1.15^{a}	0.13±0.01^{ab}	159.1±16^{ab}
Rubi	61.81±1.79^{c}	5.44±0.12^{a}	20.78±2.06^{a}	0.12±0.01^{ab}	176.1±25^{ab}

Means values ± standard deviation (n = 4) followed by different letters in the same column within the same characteristic differ significantly (Tukey test, $p < 0.05$).

plant) and 51.3% higher than 'Rubi' (74 fruits per plant), proving there is no significant correlation (r = 0.41, p > 0.05) between these characteristics. The productivity of a 12 year-old 'Fuyu' cultivar, grown in Rio das Antas (Santa Catarina, Brazil) was 14.93 t ha^{-1}, with 254 fruits per plant (Souza et al., 2011). Although, their plants were older and with a bigger number of fruits, the yields they obtained were similar to the ones found in this study, considering the same cultivar and the 'Pomelo' and 'Fuyu' ones as well. This shows that these cultivars have a great productive potential, since persimmons trees studied were only 4 years old. According to Pio (2014), the persimmon trees started commercial production at the age of three years old, however they reached maturity only at seven years old. From there on, the yield can gradually grow until the age of 15, when they stabilize. This may have been one of the factors responsible for the variation presented in yield per tree among plants of the same cultivar.

Although, 'Pomelo' produced less fruits per plant, its productivity was the same as the other varieties probably due to a greater fruit fresh mass (r = 0.60, p < 0.05), length (r = 0.66, p < 0.05) and fruit width (r = 0.58, p < 0.01) obtained by this cultivar. The average values of fresh mass (108.7 g), length (48.8 mm) and fruit width (61.3 mm) of 'Rama Forte' and 'Rubi' were significantly lower.

There were no pH differences among all the sorts of crop, with an average value of 5.41. The value obtained for 'Fuyu' persimmon fruit (5.33) in this study was lower than the one observed by Brackmann et al. (2013) in Rio Grande do Sul, Brazil. The 'Rama Forte' persimmon fruit in this study show similar results with the same crops growing in Jundiaí (São Paulo, Brazil) conditions (Mendonça et al., 2015). These results can be due to climate condition variations and experimental site, but could be also due to the fruit's ripening stage and harvesting season.

The soluble solids content also did not differ among the cultivars, with an average value of 20.48 °Brix. This value is higher than those obtained in 'Rama Forte' and 'Mikado' persimmon fruits grown in Nova Friburgo (Rio de Janeiro, Brazil) which presented, for the same characteristic, average values of 14.0 and 14.8 °Brix, respectively (Shimizu et al., 2002). Results obtained by Vieites et al. (2012) with 'Giombo' persimmon fruits grown in Avaré (São Paulo, Brazil) showed lower soluble solids content (19.33 °Brix) as compared to the current study.

Soluble solids content ranging from 14.1 to 16.1 °Brix were obtained in 'Fuyu' persimmon fruits growing in Porto Amazonas (Paraná, Brazil) and Andosol (Japan) (Porfírio-da-Silva et al., 2011; Tetsumura et al., 2015). Those values were lower than the ones obtained for all crops in the current study. The differences among the sorts of crops may be related to edaphoclimatic factors, crop cultural handling methods, fruits ripening index and postharvest storage (Krammes et al., 2005; Porfírio-da-Silva et al., 2011), which imply modifications in fruits, as well as in the conversion of sugars, synthesis of soluble molecules in the cell wall and organic acid balance (Murray and Valentini, 1998).

Regarding the acidity, 'Pomelo' persimmon fruit had the lowest value in this trait (0.11% malic acid), while the highest value was obtained in 'Rama Forte' (0.14% malic acid). Both had opposite effect for ripening index, 'Pomelo' showed higher index value than 'Rama Forte' ones, with average values of 181.8 and 145.5, respectively, due to the high negative correlation between acidity and maturation index (r = -0.82, p < 0.01). With average values of 0.12 and 0.13% in titratable acidity, and 176.1 and 159.1 in the ripening index, 'Ruby' and

'Fuyu' persimmon fruits, respectively obtained intermediate values.

Persimmons are classified as climacteric fruits, and their organic acids (malic, citric and tartaric acids) can be metabolized, being intermediate compounds of cellular respiration for energy production, and can also be converted to soluble sugars, such as glucose, fructose and sucrose. These metabolic activities may sometimes, during the natural process of fruit ripening or storage for instance, be correlated and explain differences in acidity such as the ones observed throughout the study (Porfírio-da-Silva et al., 2011).

Conclusion

Despite the differences between the time periods of some intermediate phenological phases, the time required from pruning to the harvesting of the fruits is similar among the cultivars. 'Rama Forte' and 'Fuyu' cultivars produce more fruit per plant; however 'Pomelo' produces larger fruits, which are heavier and with less acidity.

Conflict of interests

The authors have not declared any conflict of interest.

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