Harvest season, productivity and physicochemical quality of peach fruits grown in Dois Vizinhos, Paraná State, Brazil

Época de colheita, produtividade e qualidade físico-química de frutos de pessegueiros cultivados em Dois Vizinhos, PR

Gilmar Antônio Nava[1]*; Eder Oneide Kurschner[2]; Dalva Paulus[1]

Highlights:

Fruits of the Rubimel cultivar matured earliest and fruits of the Eldorado cultivar, latest.

The average yield of the evaluated peach cultivars was 5.3 t ha^{-1}, ranging from 1.2 to 15.5 t ha^{-1}.

The cultivars Bonão, Charme and Eldorado were the most productive.

The availability of winter cold in 2016 was 73 % greater than in 2017.

The 2016 crop season provided higher productivity, with fruits of greater biomass and firmness of pulp.

Abstract

The objective of this study was to determine the harvest time, main components of yield and the physicochemical quality attributes of peach cultivars produced in a subtropical climate. The study was carried out in the Fruit Growing sector of the Federal Technological University of Paraná, Campus Dois Vizinhos, Paraná State, Brazil. The main components of yield and estimated productivity, background color of the epidermis, pulp firmness, soluble solids (SS), titratable acidity (TA) and the SS/TA ratio of 17 peach cultivars were determined for two crop cycles: 2016 and 2017. The experimental design was a randomized block with four replicates of one tree per experimental unit, in a 17 x 2 bifactorial scheme (cultivars x years). Fruits of the cultivars: Aurora-1, Bonão, Douradão, Leonense, Ouromel, Rubimel and Zilli matured early, whereas those of Eldorado and BR-1 were last to mature. The cultivars Bonão, Charme and Eldorado were the most productive. Eldorado produced the highest caliber of fruits and Bonão produced the highest number of fruits per tree. The cultivars BR-1 and Eldorado produced the sweetest fruits and Leonense, the most acidic. The 2016 crop season provided greater productivity, with fruits of greater caliber and firmness of pulp.

Key words: Quality attributes of fruits. *Prunus persica* L. Batsch. Season of maturity. Yield.

Resumo

O objetivo do trabalho foi determinar a época de colheita, os principais componentes de rendimento e atributos de qualidade físico-química de cultivares de pessegueiro produzidos em Dois Vizinhos, PR. O trabalho foi realizado no setor de Fruticultura da Universidade Tecnológica Federal do Paraná, *Campus* Dois Vizinhos. Obteve-se em duas safras agrícolas, 2016 e 2017, as datas de início de colheita, os principais componentes de rendimento e a produtividade estimada, cor de fundo da epiderme, firmeza de polpa, teores de sólidos solúveis (SS) e acidez titulável (AT), bem como a relação SS/AT (*ratio*) de 17 cultivares de pessegueiros. O delineamento experimental foi de blocos ao acaso com quatro

[1] Profs. Drs., Universidade Tecnológica Federal do Paraná, UTFPR, Dois Vizinhos, PR, Brasil. E-mail: gilmarnava@utfpr.edu.br; dalvapaulus@utfpr.edu.br

[2] Discente do Curso Agronomia, UTFPR, Dois Vizinhos, PR, Brasil. E-mail: ederkurschner@gmail.com

* Author for correspondence

repetições de uma planta por unidade experimental, num esquema bifatorial 17 x 2 (cultivares x anos de cultivo). Os frutos das cultivares Aurora-1, Bonão, Douradão, Leonense, Ouromel, Rubimel e Zilli amadureceram mais cedo, enquanto os de Eldorado e BR-1 foram os últimos a amadurecer. As cultivares Bonão, Charme e Eldorado foram as mais produtivas. Eldorado produziu o maior calibre de frutos e Bonão produziu o maior número de frutos por planta. As cultivares BR-1 e Eldorado produziram os frutos mais doces e Leonense, os mais ácidos. A safra de 2016 proporcionou maior produtividade, com frutos de maior calibre e firmeza da polpa.

Palavras-chave: Atributos de qualidade de frutos. *Prunus persica* L. Batsch. Época de maturação. Produtividade.

Introduction

The peach (*Prunus persica* L. Batsch) is a fruit species of temperate climates that needs cold during the winter rest period to overcome dormancy. However, nowadays, it is also being cultivated in subtropical and tropical regions, where there is less occurrence or even total absence of cold during this phenological phase (Souza et al., 2017). This region presents great variability in the requirement for winter cold between cultivars, as well as in the average fruit biomass and in productivity (Della Bruna, Moreto, & Dalbó, 2012).

In 2018, Brazil produced 219,598 t of peaches, cultivated over an area of 17,605 ha. By state, the biggest producers of the 2018 peach yield were Rio Grande do Sul (146,431 t), São Paulo (34,640 t), Santa Catarina (18,587 t), Paraná (11,781 t), and Minas Gerais (7,845 t) (Instituto Brasileiro de Geografia e Estatística [IBGE], 2020).

The lack of adaptation of peach cultivars to mild winters can cause insufficient and sporadic flowering, which limits fruit production (Scariotto, Citadin, Raseira, Sachet, & Penso, 2013). However, according to Citadin et al. (2014), temperatures between 7.2 °C and 12 °C can be effective in overcoming the endodormancy of the buds of cultivars with low cold requirements.

Knowledge of the adaptability and stability of fruit production in different locations or between years is crucial for increasing the potential of agricultural production (Matias, Bruckner, Silva, Carneiro, & Oliveira, 2017). In order to make the cultivation of peaches technically and economically viable in regions with a low occurrence of winter cold, the choice of well adapted cultivars is one of the first actions needed to improve orchard yield (Souza, Ramos, Lima, Florentino, & Escobedo, 2011).

Knowing the expected harvest date of a cultivar can help peach producers to plan crop management practices efficiently and, consequently, increase fruit productivity and quality (Day, Lopes, & Dejong, 2008; Leonel, Pierozzi, & Tecchio, 2011). Thus, this study investigated the time of harvest, main components of fruit yield, and physicochemical quality of peaches produced in a region with low cold accumulation.

Materials and Methods

The study was carried out in the Fruit sector of the Federal Technological University of Paraná, Campus Dois Vizinhos (25°45'00" S, 53°03'25" W, at 546 m elevation (Instituto Nacional de Meteorologia [INMET], 2018). The local climate is humid and subtropical (Köppen classification: Cfa) with an average annual temperature of 22 °C in the hottest months, below 18 °C in the coldest months, and an average rainfall of 2,025 mm year^{-1} (Alvares, Stape, Sentelhas, Gonçalves, & Sparovek, 2013).

The peach tree cultivars evaluated during the 2016 and 2017 crop cycles were: Aurora-1, Bonão, BR-1, Charme, Chimarrita, Coral, Douradão,

Eldorado, Fascínio, Kampai, Leonense, Maciel, Marli, Ouromel, Regalo, Rubimel, and Zilli, all on the Capdeboscq rootstock. Trees were treeed at a spacing of 4.0 x 5.0 m in the orchard. The experimental design was completely randomized, with four replications of one tree per experimental unit in a 17 x 2 bifactorial scheme (cultivars x years). The Fascínio, Kampai, Regalo, and Zilli cultivars were treeed in 2014, and the others in 2010. The tree conduction system adopted was the vase. All the trees were managed according to the precepts of integrated peach production (Fachinello, Coutinho, Marodin, Botton, & May De Mio, 2003).

At the bud swelling stage of each cultivar, a mixture of 0.5 % hydrogenated cyanamide and 1.0 % mineral oil was applied to the buds to artificially stimulate budding and floral opening. When the fruits of each cultivar reached 15 to 20 mm in diameter, manual fruit thinning was performed to a distance of 8 to 10 cm between fruits. After 15 days of fruit thinning for each cultivar, the remaining fruits were counted per tree using a manual register.

Evaluated during the harvest windows: date of the start of the fruit harvest, number of fruits per tree, fresh fruit biomass (g), production (kg per tree) = [fruits per tree x fresh biomass of fruits (g)] / 1000, and productivity (t ha^{-1}) = [kg per tree x trees ha^{-1} (n = 500)] / 1000. Fresh fruit biomass was determined with all the fruits harvested per tree using a semi-analytical balance Shimadzu BL3200H.

From the largest harvest of each cultivar (full harvest), 10 fruits per experimental unit (tree) were randomly sampled for physicochemical analysis. The parameters $L*$ (lightness) and the coordinates a^* and b^* of the background color of the epidermis of these fruits were evaluated with a digital colorimeter Konica-Minolta CR400. Pulp firmness was determined using a manual penetrometer

Instruterm PTR-100 with an 8 mm diameter tip. The soluble solids (SS) content was measeued by digital refractometer Hanna HI96801 and the values were corrected for a temperature of 20 ºC. The levels of titratable acidity (TA) were obtained by titration using a digital pH meter BEL PHS3BW, from aliquots of 10 ml of juice obtained from a juicer-type centrifuge Mondial CF-01 in 90 ml of distilled water, with 0.1 N of NaOH until pH 8.1. The results of these analyses were used to calculate the SS/TA ratio for each cultivar.

The Lilliefors Normality test and the required transformations were applied to the average data: Root (Yij + 1/2) for number of fruits per tree, parameter $L*$ for background color, and for SS/TA ratio e; $\log_{10}$ (Yij + 1) for productivity, parameters $a*$ and $b*$ for background color, and SS. Using the statistical program Genes (Cruz, 2006), the data were subjected to variance analysis and, when significant, the averages were grouped by the Scott & Knott test (p ≤ 0.05).

Results

Fruit harvest dates

In 2016, the cultivars that showed earlier fruit maturation were Aurora-1, Bonão, Douradão, and Ouromel (10 October), followed by Rubimel and Zilli (14 October), whereas later fruit maturation was displayed by BR-1(25 November) and Eldorado (2 December). In 2017, the earliest ripening cultivars were Rubimel and Leonense (12 October), followed by Coral and Zilli (18 and 19 October, respectively) and then by Marli and Ouromel (22 October), and Bonão (23 October). The cultivars Eldorado and BR-1 again showed the latest fruit maturation, from mid-November (Table 1).

Table 1
Harvest start dates (day/month) for the different peach cultivars during the 2016 and 2017 crop cycles. Dois Vizinhos, Paraná State, Brazil

Cultivars	2016	2017	Dates
Aurora-1	10/10	26/10	18/10
Bonão	10/10	23/10	16/10
BR-1	25/11	17/11	21/11
Charme	03/11	26/10	30/10
Chimarrita	07/11	26/10	01/11
Coral	09/11	18/10	29/10
Douradão	10/10	26/10	18/10
Eldorado	02/12	20/11	26/11
Fascínio	11/11	26/10	03/11
Kampai	03/11	26/10	30/10
Leonense	(-)	18/10	18/10
Maciel	16/11	14/11	15/11
Marli	07/11	22/10	30/10
Ouromel	10/10	22/10	16/10
Regalo	11/11	14/11	12/11
Rubimel	14/10	12/10	13/10
Zilli	14/10	19/10	16/10

(-) No information.

Fruit yield components

After standard thinning, the average number of fruits per tree (145) was similar between the 2016 and 2017 crops. Except for Aurora-1, Kampai, Ouromel, and Rubimel, which had the highest number of fruits per tree in 2017, all the other cultivars either had their highest fruit number in 2016, or statistically equal fruit numbers between the two crop cycles. Comparing the cultivars within each crop cycle, Bonão produced the highest number of fruits in 2016, and in 2017, Aurora-1, Bonão, Kampai, and Ouromel were the top producers (Table 2).

All cultivars produced a higher fresh fruit biomass during the 2016 season, except BR-1, Fascínio, and Leonense, which were statistically equal between the two crops (Table 2). In 2016, the cultivars Eldorado and Marli produced the largest fruits, both averaging 128.6 g, followed by the fruit sizes of Charme, Chimarrita, Coral, Douradão, Leonense, Maciel, Rubimel, and Zilli. The cultivar BR-1 (47.3 g) produced fruits with the lowest fresh biomass. In 2017, the cultivars Chimarrita, Eldorado, Fascínio, Leonense, Rubimel, and Zilli produced the largest fruits, whereas the fruits of the Aurora-1 and Ouromel cultivars were the smallest (Table 2).

The average productivity of the peach cultivars was 5.3 t ha^{-1} (Table 2) which was substantially lower than the Brazilian average of 17 t ha^{-1} in the 2016-2017 crop season (IBGE, 2020).

The productivity of most cultivars was higher in 2016 than 2017, probably the result of greater fruit development. The most productive cultivars (t ha^{-1}) were Bonão (20.2), Charme (16.7), and Eldorado (14.5) (Table 2), with Bonão above, and Charme close to the national average of peach tree

productivity (IBGE, 2020). In 2017, cultivars with statistically significant low productivity (t ha⁻¹) were Zilli (2.4), Marli (2.1), Coral (1.4), BR-1 (1.1), Leonense (0.9), and Regalo (0.8) (Table 2). Lower fruit productivity in 2017 could have been due to less rainfall and higher average September temperatures than in the same period in 2016 (Figure 1).

Table 2
Fruit yield components of peach cultivars during the 2016 and 2017 crop cycles. Dois Vizinhos, Paraná States, Brazil

Cultivar/ Year	Number of fruits/ tree			Fresh fruit biomass (g)			Productivity (t ha⁻¹)		
	2016	2017	Average	2016	2017	Average	2016	2017	Average
Aurora-1	232 bB*	387 aA	309	71.1 dA	36.9 cB	54.0	8.3 bA	7.1 aA	7.7
Bonão	595 aA	262 aB	429	66.3 dA	51.8 bB	59.0	20.2 aA	6.8 aB	15.5
BR-1	170 cA	43 cB	89	47.3 eA	51.4 bA	49.3	4.2 cA	1.1 bB	2.6
Charme	366 bA	188 bB	277	93.8 bA	64.2 bB	79.0	16.7 aA	6.0 aB	11.3
Chimarrita	60 dA	93 cA	76	104.6 bA	76.5 aB	90.5	3.1 dA	3.6 aA	3.3
Coral	56 dA	54 cA	55	108.4 bA	53.8 bB	81.1	3.0 dA	1.4 bA	2.2
Douradão	103 cA	149 bA	126	101.5 bA	59.6 bB	80.6	5.3 cA	4.4 aA	4.8
Eldorado	234 bA	138 bA	186	128.6 aA	74.9 aB	101.7	14.5 aA	5.1 aB	9.8
Fascínio	83 dA	146 bA	114	86.9 cA	76.7 aA	81.8	3.7 cA	5.3 aA	4.5
Kampai	44 dB	250 aA	147	81.0 cA	51.7 bB	66.4	1.8 dB	6.4 aA	4.1
Leonense	34 dA	22 cA	28	92.5 bA	80.3 aA	86.4	1.6 dA	0.9 bA	1.2
Maciel	118 cA	112 cA	115	99.8 bA	59.1 bB	79.4	5.5 cA	3.3 aA	4.4
Marli	79 dA	75 cA	77	128.6 aA	53.6 bB	91.1	5.2 cA	2.1 bB	3.6
Ouromel	130 cB	272 aA	201	88.5 cA	43.1 cB	65.8	5.7 cA	5.9 aA	5.8
Regalo	62 dA	25 cA	43	76.3 dA	61.3 bB	68.8	2.2 dA	0.8 bA	1.5
Rubimel	42 dB	150 bA	96	107.5 bA	71.5 aB	89.5	2.2 dB	5.4 aA	3.8
Zilli	144 cA	61 cB	103	98.8 bA	79.7 aB	89.3	7.1 bA	2.4 bB	4.7
Average	150	141	145	93.0	61.5	77.3	6.5	4,0	5.3
CV (%)	25.0			11.8			23.6		

*Means followed by the same lowercase letter in columns and uppercase in rows, do not differ among themselves as determined by the Scott & Knott test (p ≤ 0.05); CV = Coefficient of variation.
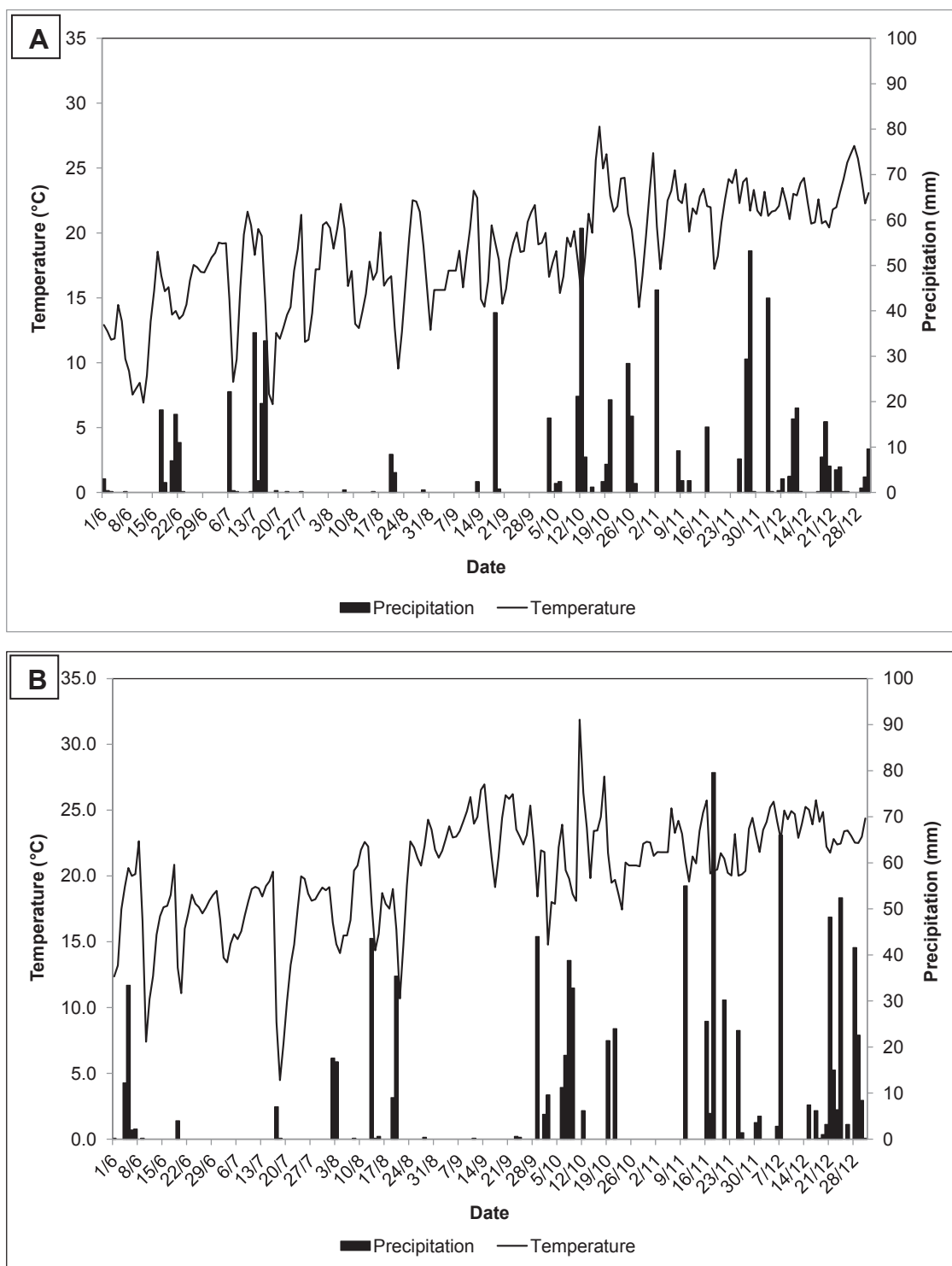
Figure 1. Average daily air temperature and rainfall recorded at the INMET station, from 1 June to 31 December in 2016 (A) and 2017 (B). Dois Vizinhos, Paraná State, Brazil.

Physicochemical fruit quality

Regarding the chemical fruit quality of the fruits, interaction between cultivars and the 2016 and 2017 crop cycles was observed for SS and TA contents, and the SS/TA ratio (Table 3).

Table 3
Chemical fruit quality of peach cultivars produced during the 2016 and 2017 crop cycles. Dois Vizinhos, Paraná States, Brazil

Cultivar/ Year	SS (°Brix)			TA (%)			SS/TA ratio		
	2016	2017	Average	2016	2017	Average	2016	2017	Average
Aurora-1	10.0 bB*	12.1 cA	11.1	0.76 cA	0.49 eB	0.62	13.2 cB	25.5 bA	19.4
Bonão	8.1 cB	9.4 dA	8.8	0.74 cA	0.66 dA	0.70	11.1 dB	14.5 dA	12.8
BR-1	13.7 aB	17.7 aA	15.7	0.47 dA	0.61 dA	0.54	29.2 aA	29.4 aA	29.3
Charme	12.9 aA	11.2 cA	12.1	0.62 cA	0.49 eA	0.55	20.6 bA	23.1 bA	21.9
Chimarrita	11.8 aA	13.2 cA	12.5	0.64 cA	0.50 eA	0.57	18.8 bB	26.3 bA	22.5
Coral	12.3 aA	12.0 cA	12.1	0.46 dA	0.50 eA	0.48	26.8 aA	24.1 bA	25.4
Douradão	10.0 bB	13.3 cA	11.7	0.58 dA	0.56 eA	0.57	17.8 bB	24.2 bA	21.0
Eldorado	13.0 aB	18.0 aA	15.5	1.37 bA	1.02 cB	1.20	9.5 dB	17.6 cA	13.5
Fascínio	12.7 aA	13.4 cA	13.0	0.70 cA	0.55 eB	0.63	18.5 bB	24.7 bA	21.6
Kampai	13.1 aA	12.5 cA	12.8	0.66 cA	0.47 eB	0.57	20.0 bB	27.5 aA	23.8
Leonense	13.0 aB	15.9 bA	14.5	1.70 aA	1.54 aB	1.62	7.7 eB	10.5 eA	9.1
Maciel	13.8 aA	15.0 bA	14.4	1.26 bA	1.28 bA	1.27	11.0 dA	11.8 eA	11.4
Marli	13.3 aA	12.7 cA	13.0	0.44 dA	0.41 eA	0.42	30.4 aA	31.8 aA	31.1
Ouromel	11.4 bA	11.7 cA	11.5	0.58 dA	0.50 eA	0.54	19.7 bA	23.6 bA	21.7
Regalo	10.9 bB	12.7 cA	11.8	0.57 dA	0.71 dA	0.64	19.4 bA	18.3 cA	18.9
Rubimel	10.6 bB	15.4 bA	13.0	0.63 cA	0.51 eA	0.57	16.9 bB	30.7 aA	23.8
Zilli	10.5 bB	13.9 cA	12.2	0.68 cA	0.63 dA	0.66	15.4 cB	22.0 bA	18.7
Average	11.8	13.5	12.7	0.76	0.67	0.72	18.0	22.7	20.3
CV (%)		3.4			14.1			6.5	

*Means followed by the same lowercase letter in columns and uppercase in rows, do not differ among themselves as determined by the Scott & Knott test (p ≤ 0.05); CV= Coefficient of variation.

The SS content indicated that most cultivars produced fruits in 2017 that were approximately 15 % sweeter than those produced in 2016 (Table 3). The sweetest fuits of all were produced by the cultivars BR-1 (17.7 ºBrix) and Eldorado (18.0 ºBrix) in 2017. Bonão, a cultivar commonly harvested for industrial processing, produced the least sweet fruits in both years (8.1 ºBrix and 9.4 ºBrix, respectively).

The TA levels in fruits of Aurora-1, Eldorado, Fascínio, Kampai, and Leonense were lowest in 2017, whereas TA values of the other cultivars were statistically equal between the two crops. The cultivar with the highest fruit TA index in both harvests was Leonense, followed by Maciel and Eldorado in 2016, and by Maciel in 2017 (Table 3). Fruits of the white pulp cultivars: BR-1, Coral, Kampai, and Marli, and the yellow pulp Rubimel had the highest SS/TA ratios in one or both crop cycles.

Regarding the physical fruit quality, an interaction between the two experimental factors (cultivars and crop cycles) was observed only for parameter a* of epidermal background color, and pulp firmness. For the L* and b* parameters of epidermal background color, there was no statistical difference within each factor in isolation (Table 4).

With few exceptions, the parameter $a*$ values of the fruits were higher in 2017 (Table 4), indicating greater biosynthesis and accumulation of red pigments in the epidermis, which made

the fruits more visually attractive. In 2016, fruits of the cultivar Bonão showed a high index of red epidermal pigmentation in comparison with fruits of the other cultivars, even though Bonão fruits are cultivated for industrial processing. The cultivars that produced fruits with the lowest parameter $a*$ values in 2016 were Fascínio, Leonense, Ouromel, Regalo, Rubimel, and Zilli. In 2017, the cultivars Leonense and Regalo again accumulated less red epidermal pigment (Table 4).

Table 4
Physical fruit quality of peaches produced during the 2016 and 2017 crop cycles. Dois Vizinhos, Paraná States, Brazil

Cultivar/ Year	Epidermis color ($L*$)	Epidermis color ($a*$)			Epidermis color ($b*$)	Pulp firmness (kg)		
	Average	2016	2017	Average	Average	2016	2017	Average
Aurora-1	63.8 ns	9.3 bB*	25.7 aA	17.5	31.5 ns	6.4 aA	4.0 bB	5.2
Bonão	64.6	58.0 aA	11.8 aB	34.9	67.0	3.9 bA	2.9 bA	3.4
BR-1	54.6	5.2 cB	20.4 aA	12.8	26.2	3.3 bA	2.5 bA	2.9
Charme	46.4	10.1 bA	13.9 aA	12.0	23.8	6.8 aA	2.0 bB	4.4
Chimarrita	56.4	6.0 cB	14.3 aA	10.1	26.1	8.1 aA	5.5 aB	6.8
Coral	52.6	3.0 cB	16.6 aA	9.8	26.2	4.9 bA	2.4 bB	3.6
Douradão	44.2	2.8 cB	15.9 aA	9.3	28.9	8.3 aA	3.8 bB	6.1
Eldorado	61.5	3.0 cB	12.9 aA	8.0	40.9	4.5 bA	3.4 bA	3.9
Fascínio	59.8	1.7 dB	12.0 aA	5.1	30.1	6.7 aA	6.7 aA	6.7
Kampai	47.5	7.7 bB	15.1 aA	11.4	22.8	7.1 aA	4.0 bB	5.6
Leonense	58.1	1.9 dB	5.9 bA	2.0	43.2	5.9 aA	6.2 aA	6.1
Maciel	58.3	2.7 cB	14.9 aA	8.8	43.5	5.5 aA	6.2 aA	5.9
Marli	54.7	5.3 cB	11.3 aA	8.3	27.1	6.2 aA	5.6 aA	5.9
Ouromel	51.8	1.0 dB	17.6 aA	9.3	34.8	6.4 aA	1.4 bB	3.9
Regalo	56.7	1.6 dB	7.6 bA	4.6	51.2	4.8 bB	6.8 aA	5.8
Rubimel	52.6	0.6 dB	17.1 aA	8.8	34.4	5.8 aA	2.6 bB	4.2
Zilli	47.0	0.6 dB	12.5 aA	6.5	30.3	6.3 aA	5.9 aA	6.1
Average	54.8	6.7	14.4	10.6	34.6	5.9	4.2	5.1
CV (%)	41.7		21.6		28.2		26.2	

*Means followed by the same lowercase letter in columns and uppercase in rows, do not differ among themselves as determined by the Scott & Knott test (p ≤ 0.05); ns= not significant; CV= Coefficient of variation.

The pulp firmness of the fruits was higher for the 2016 crop, or statistically equal to that for the 2017 crop, depending on the cultivar (Table 4). An exception was the cultivar Regalo, which showed firmer fruits in 2017. During both crop cycles, the cultivars Chimarrita, Fascínio, Leonense, Maciel, Marli, and Zilli produced fruits with greater pulp firmness, and Bonão, BR-1, Coral, and Eldorado produced lesser firm fruits (Table 4).

Discussion

Fruit harvest dates

Peach harvest dates depend largely on the cultivars and the weather conditions of the places of cultivation, especially the temperature. For the Kampai cultivar, for example, the fruit harvest in Pelotas (Rio Grande do Sul), usually starts in mid-November; in Atibaia (São Paulo), it starts in the

second half of October (Raseira, Nakasu, Ueno, & Scaranari, 2010) and, in Dois Vizinhos (Southwest of Paraná), peaches are harvested from the end of October to the beginning of November, depending on the year (Table 1).

The early harvest of peaches, carried out in mid-October for the cultivars Aurora-1, Bonão, Douradão, Fascínio, Ouromel, Rubimel, and Zilli, can provide a great competitive advantage for the producer by enabling the commercialization of their produce at a time of low supply and best price. In practice it is also observed that the fruit of the earliest peach cultivars suffers less damage from pests and diseases, reducing the need for application of pesticides. These two factors can increase profitability for producer and hence enable the cultivation of peaches in subtropical and/or tropical regions.

Fruit yield components

The low number of fruits produced by the Kampai cultivar could be attributed to the immaturity of the trees at the time of this study, with the expectation of an increase in number of fruits in subsequent seasons as the trees reached reproductive maturity.

The higher fresh fruit biomasses observed in 2016 for most of the cultivars suggest that, in this year, the greater number of winter hours of cold (HC) below 7.2 °C (185 HC in 2016 against 107 HC in 2017) and the weather conditions in spring were more favorable for peach trees, stimulating greater bud sprouting intensity, greater vegetative growth of branches, increased photosynthetic rate and, consequently, greater availability of photoassimilates for fruit growth. In 2017, the low fresh fruit biomasses of the cultivars Aurora-1 and Ouromel could be explained by a combination of the less favorable HC and weather conditions, which would have limited sprouting and fruit quality, and the large number of fruits produced per tree which would have increased competition for photoassimilates between individual fruits.

The quality of fruit, including peaches, is determined by a set of characteristics, such as size (biomass), color, flavor and phytosanitary status. Fruits with good characteristics facilitate marketing, enable the opening of new markets, attract consumers (Dussi, Giardina, Reeb, Bernardin, & Apendino, 2006), and generally provide greater income for producers. Fruit size is determined by the genetic characteristics of each cultivar, influenced by the general management in the orchard (Giovanaz et al., 2014).

The majority of the cultivars were more productive in 2016, however the cultivar Kampai was an exception as it was more productive in 2017 than in 2016, possibly due to increased age of the trees and associated reproductive maturity. The greater accumulated rainfall in September 2016 compared to the same period in 2017 is likely to have facilitated the observed higher productivity of most cultivars that year.

In the municipality of Lapa, Paraná, the cultivars Chimarrita, Eldorado, Maciel, and Marli were the most productive (Alves, Silva, May de Mio, & Biasi, 2012). A study by Souza et al. (2017), showed the cultivars Bonão, Ouromel-4, and Maciel to have greater adaptability and stability of the vegetative phase and Ouromel-4 showed the greatest adaptability and stability of the reproductive phase under the subtropical conditions in Lavras, Minas Gerais.

Despite the important effects of climatological factors during flowering and fruit development on the productivity of cultivars, it is possible to infer that, with the exception of Bonão, Charme, and Eldorado, all other cultivars evaluated in this study in Dois Vizinhos, Paraná State require more winter cold than occurred in 2016 (185 HC). It is also important to note that the trees of the cultivars Fascínio, Kampai, Regalo, and Zilli were younger than the others, and they had not reached full reproductive maturity at the time of the study. These cultivars should be evaluated for another two or

three crop cycles. However, the productivity of the Kampai trees increased by 355 % between the 2016 and 2017 crop cycles, whereas the productivity of the Zilli trees decreased by 296 % (Table 2). This finding suggests that Kampai is a cultivar better adapted to the local climate than Zilli. The Regalo trees seemed to require more winter cold (over 185 HC) than the Zilli trees, indicating that Zilli is possibly the least adapted of the four cultivars.

Other factors may have contributed to the low yields of some of the peach cultivars evaluated in this study, including the occurrence of frost recorded on 17 and 18 July 2016 and 18 and 19 July 2017 (data not shown). The occurrence and intensity of frost, depending on the phenological stage of the peach trees, can cause abscission of flowers and fruits, especially if it occurs during the initial stage of development (Assmann et al., 2008).

For other cultivars, low productivity can be associated with relatively prolonged periods of water deficit (Mirás-Avalos et al., 2013), such conditions occurred between mid-July and mid-September, 2016 (Figure 1A) and between late August and late September, 2017 (Figure 1B). This environmental factor is likely to have contributed to a lower rate of fruit growth and, consequently, to the low productivity of most of the evaluated cultivars. The water deficit and/or high temperatures, especially in 2017, might have increased the abscission of flowers and particularly of fruits in early development. However, it is possible that some cultivars may have benefited from short periods of water deficit, during both years, especially while flowering and at the start of fruit development. These dry periods may have facilitated adequate pollination and/or reduced the development of diseases of the flowers and fruits.

According to Nava et al. (2009), record high temperatures (daytime and/or nighttime) during pre-flowering, full bloom and initial fruit development drastically reduced the effective fruiting and productivity of the peach, cultivar Granada, in

southern Brazil. These authors suggest that the high temperatures caused a delay in the development of the ovular embryo sac, collapse (abortion), and low rates of pollen grain germination, as well as the abscission of fruits in their initial stage of development.

Physicochemical fruit quality

According to Morais, Xavier, Silva, Oliveira and Bruckner (2017), the physicochemical fruit quality of peaches intended for fresh consumption varies between crops, and this variation depends on, among other factors, the conditions of the place of cultivation.

The high average SS content observed in the fruits of the majority of the cultivars in 2017 suggested that, due to the failure of sprouting of the vegetative buds as a consequence the scarcity of winter cold, more light entered the tree canopies and reached the developing fruits, resulting in their sweetness. Lower accumulated precipitation and, consequently, greater solar radiation in September 2017 were also possible contributing factors to the high levels of SS and red pigment in the epidermis.

Another factor that may have contributed to this result was the smaller size of the fruits produced in 2017 (Table 2), probably influenced by the limited amount of winter cold and the lower rainfall, leading to an increase in their sugar concentration. On the other hand, the higher levels of tree leafing in 2016, together with failure to perform green pruning most likely restricted the entry of light into the canopy, possibly increasing the acidity in the fruits of the Aurora-1, Eldorado, Fascínio, Kampai, and Leonense cultivars.

It is suggested that the higher values of the SS/TA ratio in fruits of the cultivars BR-1, Coral, Kampai, Marli (white pulp), and Rubimel (yellow pulp) were mainly due to the low acidity of the fruits (Table 3). Based on this quality attribute, these would be the more suitable cultivars for

fresh consumption, however the same did not have good climate adaptation in the Southwest region of Paraná, with the exception of Kampai, which needs to be studied further until the trees of this cultivar reach reproductive maturation.

The ideal SS/TA ratio range for fresh consumption peach cultivars varies from 13.3-26.7 (Chitarra & Chitarra, 2005). For most of the cultivars researched in this study, the ratio was within this range with an average of 20.3 (Table 3), indicating that the fruits produced in Dois Vizinhos, Paraná were within the quality standards required by the consumer for this ratio. The dual-purpose cultivars Leonense (9.1), Maciel (11.4), and Bonão (12.8), had the lowest SS/TA ratios because they had, especially in the first year, higher levels of titratable acidity in their fruits (Table 3).

When grown in Araucária, Paraná, the fruits of the Douradão and Rubimel cultivars showed a better balance between SS and moderate acidity, and matured earlier than those produced by Charme and Chimarrita (Alves et al., 2018). The fruits of the cultivars Coral and Rubimel showed a better balance between SS and TA when grown in Viçosa, Minas Gerais (Matias et al., 2014), demonstrating the effect of different edaphoclimatic conditions on the variability of the chemical attributes related to fruit quality.

The higher values obtained for parameter *a** of peach epidermis background color for most of the cultivars in 2017 were in line with what has already been discussed for fresh fruit biomass and SS content, particularly that, in 2017, there was a lower rate of bud sprouting and less vegetative growth of the branches, enabling a higher incidence of solar radiation to reach the fruits, thus increasing their epidermal pigmentation.

Regarding pulp firmness, in addition to genetics (intrinsic differences between the cultivars), a possible explanation for the observed variability, as well as for parameter *a** of epidermal background color, could be associated with the differential

ripening of fruits between cultivars and growing seasons.

Conclusion

Under the edaphoclimatic conditions of the study site, it can be concluded that:

The fruits of the cultivars: Aurora-1, Bonão, Douradão, Fascínio, Ouromel, Rubimel, and Zilli matured early, whereas Eldorado and BR-1 matured later.

Bonão, Charme, and Eldorado were the most productive cultivars. Bonão produced a large number of fruits per tree. Eldorado produced the highest caliber of fruits. BR-1 and Eldorado produced the sweetest fruits, and Leonense produced fruits with greater acidity.

The 2016 crop season provided greater productivity, with fruits of greater caliber and firmness of pulp.

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