Phenology and fruit quality of peach tree cultivars under the subtropical climatic conditions of Cerro Largo, RS, Brazil

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Abstract – Knowledge about local microclimatic conditions and their influence on flowering, vegetative buds, endodormancy release, phenology, and the production and quality of peaches is essential for the successful introduction of varieties adapted to the region. This study aimed to evaluate the adaptability of four peach cultivars to the edaphoclimatic conditions of the municipality of Cerro Largo, Rio Grande do Sul, Brazil, from 2019 to 2020. The experimental design was completely randomized, with four cultivars (BRS Kampai, BRS Regalo, Chimarrita, and Eldorado) and nine replications. The plants were arranged in four rows, with 2m between plants and 3.5m between rows, and trained in a Y-system. This study evaluated the following parameters: dates of the phenological stages of flowering and sprouting, vegetative growth, fruit production, quality attributes, and weather conditions. Under the experimental conditions, BRS Kampai showed earlier sprouting and flowering. The Eldorado cultivar showed the longest length of flowering and sprouting. BRS Regalo showed the highest vegetative growth and fruit yield values and was the most adapted to the studied region. The Chimarrita cultivar had the highest average fruit mass and the largest fruit sizes. Eldorado and BRS Regalo had firmer fruits while BRS Kampai, BRS Regalo, and Chimarrita showed the expected values for the TSS, TTA, pH, and TSS/ATT ratio parameters, producing high-quality fruits for fresh consumption.

Index terms: *Prunus persica*; Phenology; Yield; Fruit Quality; Chilling hours.

Fenologia e qualidade de frutos de cultivares de pessegueiro às condições subtropicais de Cerro Largo, RS, Brasil

Resumo – O conhecimento das condições microclimáticas locais e de sua influência na formação das gemas floríferas e vegetativas, na superação da endodormência, na fenologia, na produção e na qualidade de frutos do pessegueiro é fundamental para a implantação de variedades adaptadas à região, a fim de obter êxito com a espécie. O objetivo deste estudo foi avaliar o desempenho de quatro cultivares de pessegueiro para as condições edafoclimáticas do município de Cerro Largo, RS. O experimento foi realizado durante os anos de 2019 e 2020. O delineamento experimental foi inteiramente casualizado, com quatro cultivares (BRS Kampai, BRS Regalo, Chimarrita e Eldorado) e nove repetições. As plantas estão dispostas em quatro linhas, com espaçamento de 2m entre plantas e 3,5m entre linhas, conduzidas em sistema Y. Foram avaliados: datas dos estádios fenológicos de florescimento e brotação, crescimento vegetativo, produção e atributos de qualidade dos frutos, bem como as condições meteorológicas. Nas condições avaliadas, BRS Kampai apresentou brotação e floração mais precoce. Já Eldorado teve maior duração dos períodos de floração e brotação. BRS Regalo apresentou maior crescimento vegetativo e produtividade de frutos, mostrando-se mais adaptada para a região de estudo. Chimarrita registrou maior massa média dos frutos, com maiores dimensões. Eldorado e BRS Regalo apresentaram os frutos mais firmes. BRS Kampai, BRS Regalo e Chimarrita apresentaram características de SST, ATT, pH e ratio previamente esperadas, o que proporciona frutos de qualidade para consumo *in natura*.

Termos para indexação: *Prunus pérsica;* Fenologia; Produtividade; Qualidade dos frutos; Horas de frio.

Introduction

In Brazil, the edaphoclimatic conditions of the states in the South region and part of the states in the Southeast region of Brazil favor the production and, consequently, the commercial exploitation of peaches and nectarines. Peach cultivation—*Prunus persica* (L.) Batsch—stands out in Rio Grande do Sul (RS), with a significant production due to the climatic conditions, the proximity to preservation industries, and the genetic improvement program for adapted cultivars (FRANZON & RASEIRA, 2014).

Peach is a temperate fruit species that has adapted to subtropical climate conditions (RASEIRA & NAKASU, 2002) due to many breeding studies, allowing its development in regions with milder

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winters.

The plants have a dormancy stage in which their development stabilizes. This dormancy is only overcome with an accumulation of winter chill hours below 7.2°C. The lack of this accumulation promotes low sprouting, uneven flowering, and reduced effective fruiting (LEITE et al., 2004).

Since each cultivar has different climatic requirements, the study of plant phenology can help assess if a particular cultivar adapts to the region and identify the timing of important phenological stages, such as sprouting, flowering, and ripening (LAZZARI, 2011).

The climatic elements vary depending on the location, especially the air temperature, directly influencing the flowering, sprouting, and fruiting of the peach. Therefore, understanding the local microclimatic conditions and their influence on flowering, vegetative buds, endodormancy release, and the phenological and productive characteristics of this fruit is important to successfully introduce peach varieties adapted to the region (NIENOW & FLOSS, 2003).

Considering the need of producers for cultivars that meet the demands of the consumer market and the lack of studies on the recommendation of cultivars for the studied region, this study aimed to evaluate the adaptability of peach cultivars to the climatic conditions of the municipality of Cerro Largo, Northwestern Rio Grande do Sul, Brazil.

Material and methods

The study was conducted in an orchard in the experimental area of the Federal University of Fronteira Sul (UFFS), Campus Cerro Largo, RS (28°08' S 54°45' W; 260m), where the soil is classified as a red latosol of the Santo Ângelo mapping unit (EMBRAPA, 2006), from 2019 to 2020. The region has a humid subtropical climate, with hot summers and no dry season (Cfa), according to the Köppen climate classification (ALVARES et al., 2013).

The orchard received in October 2017 four peach cultivars: BRS Kampai, BRS Regalo, Chimarrita, and Eldorado, with all plants grafted on the Capdeboscq rootstock. The plants were arranged in four rows, with 2m between plants and 3.5m between rows, and trained in a Y-system. The orchard was managed with ecological practices. The experimental design was completely randomized, with four cultivars and nine replications, in which the experimental unit included a single plant.

For the weekly evaluation of sprouting and flowering phenology, two branches from each quadrant were selected and identified with ribbons, their length was measured, and the number of buds was counted. The evaluations were performed after the vegetative rest period, observing the beginning of flowering and sprouting (5%), full bloom (50%), and the final period (75%), according to the percentage of buds during open flowering or petal fall in relation to the total number of flower buds/minimum green tip stage (SOUZA, 2012). Manual thinning was performed when the fruits reached about 20mm diameter.

For the vegetative growth analyses, the variables plant height, main stem length, secondary branch length, and trunk diameter (March to December) were evaluated monthly and the canopy diameter and the arithmetic mean of the measurements of the longitudinal and transverse trunk diameter in relation to the planting row, five centimeters above the grafting point, were estimated in December. Canopy width and thickness measurements considered the branches farthest from the center in both directions as limits. Canopy height was measured from the insertion of the first branch in the trunk and canopy volume was assessed according to Rossi (2004).

Suture diameter and average fruit mass were measured on four samples of ten commercially ripe fruits per cultivar. The yield per plant was calculated by multiplying the average fruit mass by the number of fruits per plant, and the estimated yield per hectare by multiplying the yield per plant by the population (1,433 plants ha^{-1}). Then, manual thinning was performed so as to leave four to five fruits per 2 cm of the trunk section area (SACHS et al., 1984). Pulp firmness was measured with a penetrometer. Total titratable acidity (TTA) was obtained by diluting 10mL of juice in 90mL of distilled water, followed by titration with 0.1 N sodium hydroxide (NaOH) until pH 8.1 (turning point) was reached. In this study, pH was evaluated with a digital pH meter and total soluble solids (TSS) using a portable refractometer. The TSS/TTA ratio was the quotient between the two variables. Epidermal color was analyzed by three readings at the equatorial region of the fruit using a Minolta® CR400 colorimeter, with an 8 mm aperture D65 light source. The three-dimensional reading expressed by lightness (L), color direction "a" (green to red), and color direction "b" (blue to yellow) allowed the estimation of the color hue based on the hue angle (h°=tan−1b*/a*). Analyses were performed according to the methodology proposed by the Adolfo Lutz Institute (2008).

Weather conditions were recorded every 10 minutes by a Davis® Vantage Pro2 automatic weather station located 250 meters from the cultivars. Data on rainfall, air temperature, and incident global solar radiation were also measured. The occurrence of chill hours was estimated considering temperature limits below 7.2°C, 10°C, 12°C, and 15°C (LAZZARI, 2011). The data obtained were subjected to analysis of variance and compared by Tukey's test at 5% probability of error using the SASM-Agri software.

Results and discussion

Compared to the climate normals (WREGE et al., 2011), monthly rainfall during 2019 was above normal, except in June and September. In 2020, rainfall was below normal, except from May to July, which may have compromised flowering. Solar radiation was similar to normal. Air temperature, both minimum and maximum, showed mean values above the normal range (Figure 1).

From May to October 2019, we observed 169 accumulated chill hours (CH) below 7.2°C and 424 below 10°C. In 2020, the values were 182 CH (<7.2°C) and 476 CH (<10°C). Considering climate normals (WREGE et al., 2011), the region has 137 CH (<7.2°C), which shows more chill hours below 7.2°C than the normal.

In 2019, the beginning of flowering in most cultivars was on July 12, except for BRS Kampai, which started flowering on

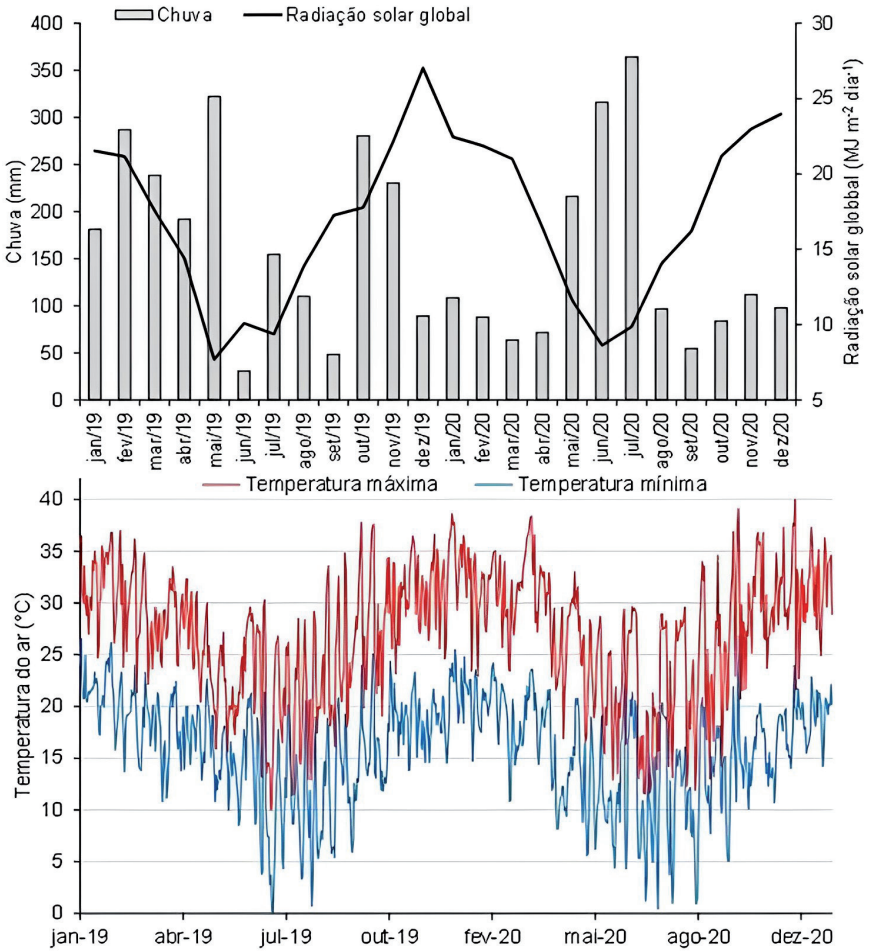

Figure 1. Monthly sum of rainfall, monthly mean of incident global solar radiation, minimum and maximum daily air temperatures from January 2019 to December 2020, in Cerro Largo, RS

Figura 1. Soma mensal da precipitação, média mensal da radiação solar global incidente, temperaturas mínimas e máximas diárias do ar de janeiro de 2019 a dezembro de 2020, em Cerro Largo, RS

July 5. The end of flowering was on July 27 for BRS Kampai, August 23 for BRS Regalo, August 16 for Chimarrita, and August 30 for Eldorado, corroborating the results found by Lazzari (2011) in the Upper and Middle Uruguay River valley, RS, for the Chimarrita and Eldorado cultivars.

In 2020, the beginning of flowering for most cultivars was on July 17, except for BRS Kampai, which started on July 10. The end of flowering was on August 10 for BRS Kampai, August 17 for Chimarrita, and August 24 for BRS Regalo and Eldorado. Regarding the total winter chill hours necessary for the beginning of flowering, except for BRS Kampai (249.7 CH<10°C), all treatments started with 279.3 CH<10°C. In 2020, the greater number of chill hours and higher rainfall in July led to a later beginning of flowering.

The beginning of sprouting for BRS Kampai was in the first days of July. In 2019, the remaining cultivars began to sprout in the first half of July. Sprouting was completed for BRS Kampai and Chimarrita in the last week of July and in early August for Eldorado and Kampai. The end of sprouting for BRS Kampai was in early August, followed by Chimarrita and, finally, Eldorado and BRS Regalo. In Pelotas, RS, Picolotto (2009) observed that the Chimarrita cultivar began to sprout in the second half of July, corroborating the results of this study, but differing from the study by Lazzari (2011), in which the Chimarrita and Eldorado cultivars entered the vegetative stage in early August in Frederico Westphalen, RS.

In 2020, BRS Kampai began to sprout on July 10 while the other cultivars entered this stage in the second half of July. Sprouting was completed for BRS Kampai in the last week of July, followed by Chimarrita, in the first week of August, BRS Regalo, in the second half of August, and Eldorado, in the first week of September. For BRS Kampai, sprouting ended in the last week of August, followed by Chimarrita and, finally, BRS Regalo and Eldorado, in the first week of September.

BRS Regalo had the largest trunk diameter averages (Table 1). According to Gonçalves (2011), the larger the trunk diameter, the greater the production load capacity, corroborating the results of this study, in which BRS Regalo had the highest fruit production per plant (Table 2).

BRS Regalo had the highest plant height. In 2020, plant height values were lower compared to 2019 due to branch bending. This cultivar also had higher canopy volume (Table 1).

Regarding yield, BRS Regalo produced 8.94kg fruits per plant (pl) and 12,770kg ha^{-1}. BRS Kampai produced 3.28kg pl^{-1} (Table 3), differing from the results found by Varago (2017) in Paraná, where this cultivar produced 8.15kg pl^{-1}. Our results for Chimarrita and Eldorado were similar to his study, with 3.97 and 5.06kg pl^{-1}, respectively. Under the conditions of Serra Gaúcha, Anzanello and Menin (2018) found high values for Chimarrita, BRS Kampai, and BRS Regalo, with 40, 27.8, and 23.3kg pl^{-1}, respectively. The yield results in this study were lower than the averages considered satisfactory. The orchard was young and the plants began to produce more expressively from the third year after planting (SIMÃO, 1998). Other factors concerning the local environment may also reduce fruit production, such as fewer chill hours (NIENOW & FLOSS, 2003).

Chimarrita produced fruits with 128.23g and 62.24mm average diameter (Table 3). These results are similar to the study by Souza (2012) in Lavras, Minas Gerais (MG), Brazil. BRS Regalo and Eldorado produced fruits with 103.5 g and 96.14g and diameters of 57.06 mm and 50.09mm, respectively.

These cultivars also produced fruits with a firmer pulp, which gave them greater strength and possibly longer

Table 1. Canopy volume, plant height, and trunk diameter of the BRS Kampai, BRS Regalo, Chimarrita, and Eldorado cultivars in 2019 and 2020 in Cerro Largo, RS

Tabela 1. Volume da copa, altura da planta e diâmetro do tronco das cultivares BRS Kampai, BRS Regalo, Chimarrita e Eldorado em 2019 e 2020, em Cerro Largo – RS

Cultivar	Canopy volume (m^3)	Plant height (m)	Trunk diameter (cm)
		2019	
BRS Kampai	N.O. [3]	2.50 b [1]	6.10 b
BRS Regalo	N.O.	2.85 a	7.80 a
Chimarrita	N.O.	2.42 b	6.72 b
Eldorado	N.O.	2.19 b	5.26 c
C.V. (%) [2]	-	9.97	8.14
		2020	
BRS Kampai	2.26 b[1]	1.99 ab	6.61 c
BRS Regalo	4.17 a	2.34 a	8.12 a
Chimarrita	2.16 b	2.02 ab	7.10 b
Eldorado	2.40 b	1.73 b	6.55 c
C.V. (%) [2]	31.40	20.88	2.88

[1] Averages followed by the same letter in the column do not differ by Tukey's test at 5% probability of error. [2] Coefficient of variation.

[3] Not observed.

[1] As médias seguidas pela mesma letra na coluna não diferem pelo teste de Tukey a 5% de probabilidade de erro. [2] Coeficiente de variação.

Table 2. Pulp firmness (PF), total soluble solids (TSS), total titratable acidity (TTA), TSS/TTA ratio, hue angle (°h), and pH of peaches of the BRS Kampai, BRS Regalo, Chimarrita, and Eldorado cultivars in Cerro Largo, RS, 2020

Tabela 2. Firmeza da polpa (FP), sólidos solúveis totais (SST), acidez titulável total (ATT), razão, ângulo de tonalidade (°h) e pH de frutas de pêssego, cultivares BRS Kampai, BRS Regalo, Chimarrita e Eldorado no ano de colheita de 2020. Cerro Largo - RS, 2020

Cultivar	Pulp firmness (N)	TSS (°Brix)	TTA (% malic acid)	pH	Ratio (TSS/ TTA)	°h
BRS Kampai	18.36 b [1]	12.33 a	0.47 b	4.18 a	26.23 a	42.93 bc
BRS Regalo	24.66 a	12.96 a	0.51 b	4.34 a	25.41 a	32.19 c
Chimarrita	19.76 b	13.52 a	0.49 b	4.16 a	27.59 a	54.03 b
Eldorado	27.51 a	12.95 a	0.94 a	3.69 b	13.77 b	76.63 a
C.V. (%) [2]	31.08	17.62	12.1	2.48	11.3	11.53

[1] Averages followed by the same letter in the column do not differ by Tukey's test at 5% probability of error. [2] Coefficient of variation.

[1] As médias seguidas pela mesma letra na coluna não diferem pelo teste de Tukey a 5% de probabilidade de erro. [2] Coeficiente de variação.

postharvest durability, resulting in pulp firmness values of 27.51 and 24.66N (Table 2). According to Chitarra and Carvalho (1985), consumers prefer peaches with a good appearance, firm texture, and without excessive softening.

We observed no significant difference in TSS among the cultivars (Table 2). However, the variation ranged from 12.33 to 13.52°Brix for BRS Kampai and Chimarrita, respectively, which are higher values than those obtained by Gonçalves (2011) in Pelotas, RS, for BRS Kampai (11.57°Brix), and by Souza (2012) in Lavras, MG, for Chimarrita (11.53°Brix). The most likely explanation concerns the higher maximum temperatures from October to December, during fruit ripening and harvest. According to Wagner Júnior et al. (2010), high daytime temperatures and mild night temperatures are the main climatic cause for increased sugar content in peaches.

Eldorado peaches had lower pH and higher TTA, allowing us to infer that the fruits of this cultivar are the most acidic among the evaluated fruits. According to Chitarra and Chitarra (2005), the relationship between soluble solids and acidity is very important for the taste of the fruit, since it defines the ripening stage. As the fruit ripens, the ratio grows due to the increase in TSS and the reduction in acidity: the higher this ratio, the more pleasant the taste and the greater the palatability for fresh consumption (MAYER et al., 2008).

BRS Kampai, BRS Regalo, and Chimarrita peaches had a TSS/TTA ratio over 15, which gave these fruits a pleasant taste. Meredith et al. (1989) state that, for peaches to be of high quality, the TSS/TTA ratio must be equal to or greater than 15.

The fruits of these cultivars also had the lowest hue angles, corroborating the results found by Gonçalves (2011) in Pelotas, RS, with the predominance of deep red, which is interesting for fruits for fresh consumption, as consumers prefer peaches of this color (SCARANARI et al., 2009).

Regarding fruit quality (Table 2), the coefficient of variation among the qualitative aspects evaluated was low, which evidences the reliability of these results. However, for pulp firmness, the coefficient of variation was high, which shows the high variability among the cultivars evaluated.

Conclusions

This study showed that BRS Kampai had earlier sprouting and flowering than the other cultivars, while, in the Eldorado cultivar, the duration of these parameters was longer.

Regarding fruit firmness, the Chimarrita cultivar had the highest average mass. In general, BRS Kampai, BRS Regalo, and Chimarrita presented adequate TSS, TTA, pH, and TSS/ATT ratio values, considering the objective of producing quality fruit for fresh consumption.

Finally, the experiment should be continued in the next harvests, since these data refer to the first year of evaluation and may vary in the next years.

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Table 3. Average fruit mass (AFM), fruit diameter, number of fruits per plant (NFP), estimated production per plant (PP), and estimated production per hectare (Pha) in Cerro Largo, RS, 2020

Tabela 3. Massa média de fruta (MFM), diâmetro da fruta, número de frutas por planta (NFP), produção estimada por planta (PP) e produção estimada por hectare (Pha) no ano agrícola de 2020. Cerro Largo - RS, 202

Cultivar	AFM (g)	Diameter (mm)	NFP	PP (kg pl^{-1})	Pha (t·ha^{-1})
BRS Kampai	96.12 b[1]	55.93 b	36.5 c	3.28 b	4.68 b
BRS Regalo	103.50 b	57.06 b	85.5 a	8.94 a	12.77 a
Chimarrita	128.23 a	62.24 a	33.7 d	3.97 ab	5.67 ab
Eldorado	96.14 b	50.09 c	50.5 b	5.06 ab	7.23 ab
C.V. (%) [2]	20.26	7.13	2.36	30.23	34.2

[1] Averages followed by the same letter in the column do not differ by Tukey's test at 5% probability of error. [2] Coefficient of variation.

[1] As médias seguidas pela mesma letra na coluna não diferem pelo teste de Tukey a 5% de probabilidade de erro. [2] Coeficiente de variação.

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