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Phenology and fruit set of peach trees cultivated in Dois Vizinhos, Paraná State, Brazil

Fenologia e frutificação efetiva de pessegueiros cultivados em Dois Vizinhos, Paraná

Claudia Regina Barbieri[1]*; Gilmar Antônio Nava[2]

Highlights

The peach cultivar Bonão presents great flowering intensity and regularity.
Coral and Kampai cultivars present fruit sets with great intensities and regularities.
The peach cultivar Riograndense presents irregular flowering and fruit production.

Abstract

Understanding the dormancy phases and dynamics of commercial cultivars in the regions where they are grown allows for the implementation of different cultural practices and aids in the understanding of the temperature requirements for collaboration with genetic improvement programs. The objective of this study was to determine the budding, flowering, and fruit set rates of peach trees cultivated in the municipality of Dois Vizinhos, Southwestern Paraná, Brazil. The present work was developed using the collection of peach trees in the fruit growing sector of the Universidade Tecnológica Federal do Paraná. Sixteen peach cultivars were evaluated: Rubimel, Leonense, Coral, Marli, Charme, Riograndense, Douradão, Chimarrita, Granada, BR-1, Bonão, and Eldorado (all planted in 2009), as well as Regalo, Kampai, Fascínio, and Zilli (planted in 2014). The experimental design was completely randomized with four replications of one plant each, in a 16 × 2 bifactorial arrangement (cultivars × year/harvest). Phenology evaluations were performed weekly by counting open (anthesis) and sprouted flower buds, and the fruit set rate was measured just before fruit thinning. Flowering (%), budding (%), and fruit set (%) rates were calculated. It was found that the year/harvest 2016 promoted the highest rates of sprouting and fruit set. The Bonão cultivar showed greater flowering intensity and regularity in the crop years evaluated (2016 and 2017). Coral and Kampai present fruit sets with greater intensities and regularities when compared to the other cultivars evaluated under the climatic condition of the municipality of Dois Vizinhos. The Riograndense cultivar showed greater irregularity in flowering and fruit production.
Key words: Floral biology. Endodormancy. Sprouting rate. Fruit set.

[1] Student of the Doctoral Course of the Postgraduate Program in Agronomy at Universidade Tecnológica Federal do Paraná, UTFPR, Câmpus Pato Branco, Pato Branco, PR, Brazil. E-mail: crbbio@hotmail.com
[2] PhD Professor at UTFPR, Câmpus Dois Vizinhos, Dois Vizinhos, PR, Brazil. E-mail: gilmarnava@utfpr.edu.br
* Author for correspondence

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Resumo

Compreender as fases e a dinâmica da dormência de cultivares comerciais na região em que essa está inserida possibilita a execução de diferentes práticas culturais e auxilia na compreensão dos requisitos de frio e calor exigidos pela mesma, colaborando principalmente com os programas de melhoramento genético. O objetivo deste trabalho foi determinar as taxas de brotação, floração e frutificação efetiva de pessegueiros sob as condições ambientais de cultivo no município de Dois Vizinhos, região Sudoeste do Paraná. O presente trabalho foi desenvolvido na coleção de pessegueiros do setor de Fruticultura da Universidade Tecnológica Federal do Paraná. Foram avaliadas 16 cultivares de pessegueiros, sendo ‘Rubimel’, ‘Leonense’, ‘Coral, ‘Marli’, ‘Charme’, ‘Riograndense’, ‘Douradão’, ‘Chimarrita’, ‘Granada’, ‘BR-1’, ‘Bonão’ e ‘Eldorado’ implantadas em 2009 e ‘Regalo’, ‘Kampai’, ‘Fascínio’ e ‘Zilli’, implantadas em 2014. O delineamento experimental foi inteiramente casualizado com quatro repetições de uma planta cada, no arranjo bifatorial 16 x 2 (cultivares x anos/safra). As avaliações de fenologia foram realizadas semanalmente através da contagem de gemas florais abertas (antese) e brotadas, e a taxa de frutificação efetiva foi realizada imediatamente antes do raleio de frutos. Foram calculadas as taxas de floração (%), de brotação (%) e de frutificação efetiva (%). Nas condições climáticas do município de Dois Vizinhos, no Estado do Paraná, verificou-se que o ano/safra 2016 promoveu as maiores taxas de brotação e frutificação efetiva. A cultivar ‘Bonão’ apresentou maior intensidade e regularidade de floração nos anos safra avaliados (2016 e 2017). As cultivares ‘Coral’ e ‘Kampai’ apresentam frutificação efetiva com maior intensidades e regularidade em relação aos demais cultivares avaliados para a condição de clima do local avaliado. A cultivar ‘Riograndense’ apresentou maior irregularidade na floração e na produção de frutos.
Palavras-chave: Biologia floral. Endodormência. Taxa de brotação. Frutificação efetiva.

Introduction

The peach tree [*Prunus persica* (L.) Batsch] starts the process of bud differentiation in summer, and as the days shorten the flower induction occurs. With the decrease in temperature, the plants begin to slow their growth to enter the dormancy phase in winter, which protects them from the reduced sunlight and lower temperatures (Wagner, Bruckner, Pio, & Citadin, 2018).

In the dormant phase, the bud accumulates chill according to the needs of each cultivar, to enable future budding and flowering (Wagner et al., 2018). Plants in temperate regions require temperatures below 7.2 °C to overcome the dormancy of the buds, while some cultivars require temperatures below 12 °C. If these levels are not met, the plants cannot overcome dormancy, and this results in decreased flowering and consequently, lower fruit production (Citadin, 2014; Souza et al., 2017).

Some regions in the State of Paraná do not have the sufficient number of cold hours (approximately 300) to overcome the dormancy of the peach trees; thus, many cultivars are not suitable for this state (Caramori et al., 2008). Therefore, the state is divided into three peach growing regions, and the southwest region is characterized by a great diversity of climate, and cultivars that require 150 to 400 chill units can be planted here (Citadin, 2014).

The behavior of cultivars in relation to cold temperature requirement can be explained through the study of phenology. This is important for defining the different phases of plant growth from sprouting to fruiting, and for presenting data on the behavior of cultivars in relation to climate change, thereby, providing opportunities to improve the cultural practices for the species (Morellato, 2007; Modesto, Vedoato, Leonel, & Tecchio, 2014).

Thus, understanding the phases and dynamics of dormancy of commercial cultivars in the region where they are grown enables the execution of different cultural practices and helps in understanding the heat and cold requirements. This can be utilized for collaboration with genetic improvement programs and agroclimatic zoning plans (Pola, Della Bruna, Back, & Moreto, 2016). This information also allows for the evaluation of edaphoclimatic adaptation and the productive potential of the species and cultivar in a given region, to provide consistent and safe recommendations for the producers.

Therefore, the objective of this study was to determine the rates of budding, flowering, and fruit set of peach trees cultivated in the municipality of Dois Vizinhos in the southwest region of Paraná, Brazil.

Materials and Methods

The present work was developed using the collection of peach trees from the fruit growing sector of the Federal Technological University of Paraná, Campus Dois Vizinhos, southwest of Paraná (25º45′00′′S, 53°03′25′′W). According to Köppen's classification, the local climate is humid subtropical Cfa, with temperatures above 22 °C in the warmest months, below 18 °C in the coldest months, and an average rainfall of 2,025 mm per year (Alvares, Stape, Sentelhas, Gonçalves, & Sparovek, 2013).

The peach trees were arranged with a spacing of 4.0 × 5.0 m between them, in a potted system. The soil was managed with a winter green cover consisting of black oats (80 kg ha^{-1}) and vetch (30 kg ha^{-1}). In summer, the spontaneous cover was managed through frequent mowing to avoid competition for water and nutrients. In the beginning of winter, the mummified fruits from the previous harvest were removed, to avoid the permanence of inoculum of the brown-rot fungi. Subsequently, the winter treatment was carried out with 5.0% sulfur-calcium syrup + mineral oil (1%).

Pruning was carried out in July, the diseased, weak, thieving branches as well as the branches facing the interior of the crown were removed. To standardize budding and flowering, the Dormex® growth regulator (0.8%) was used in association with mineral oil adjuvant (1%) approximately two weeks before the expected start of natural flowering of each cultivar, having been applied out with a back spray in a volume of 1.5 liters of syrup per plant, until it was completely runoff. The plants were fertilized in three stages: before bud sprouting with NPK mineral fertilizer (based on recommendation tables) according to Pauletti and Motta (2019); and in fruit thinning and post-harvest with N, at a total dosage of 80 kg ha^{-1}.

Sixteen peach cultivars were evaluated: Rubimel, Leonense, Coral, Marli, Charme, Riograndense, Douradão, Chimarrita, Granada, BR-1, Bonão, and Eldorado, planted in 2009; and Regalo, Kampai, Fascinio, and Zilli, planted in 2014. Despite the age difference between cultivars, it is believed that its influence on flowering, budding, pollen producing, and fruit set, it would not be as determinant as in fruit production, since all the cultivars were reproductively mature. The assessments were conducted during the 2016 and 2017 crop years.

The experimental design was completely randomized with four replications of one plant each, in a 16 × 2 bifactorial arrangement (cultivars × year/harvest). Each individual was identified and had one selected branch (per year) in each quadrant, for a total of 16 branches per cultivar, and all floral and vegetative buds were counted before the beginning of the evaluations.

Phenology evaluations were performed weekly by counting open (anthesis) and sprouted flower buds, and the fruit set rate was measured just before fruit thinning. Flowering (%), budding (%), and fruit set (%) rates were calculated. Data were subjected to the Lilliefors normality test, followed by transformation by $\sqrt{Yij} + ½$, analysis of variance (ANOVA), and comparisons of means by the Scott-Knott test at 5% significance with the aid of the GENES statistical software (Cruz, 2016).

Results and Discussions

To understand the behavior of cultivars planted in regions with few cold hours, knowledge of phenology is important to help the producer choose adapted cultivars.

Figure 1 represents the average temperatures (°C) and rainfall (mm) in the period of flowering, budding, and fruit set in 2016 (A) and 2017 (B). The data were obtained from the Meteorological Station of INMET – National Institute of Meteorology, which has a collection unit within the UTFPR – Dois Vizinhos Campus, located approximately 100 m from the collection.

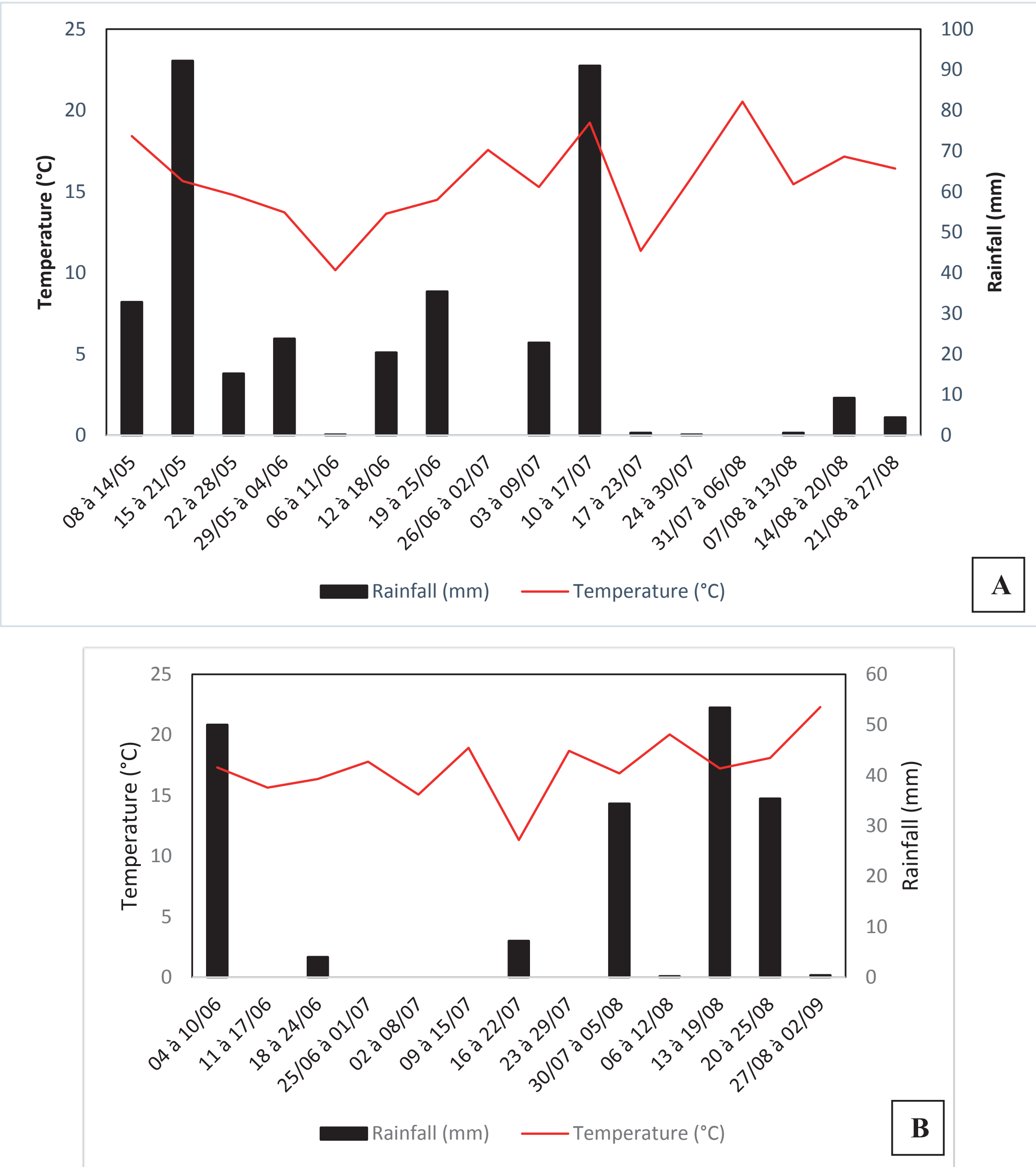

Figure 1. Average temperatures (°C) and rainfall (mm) in the period of flowering, budding, and fruit set in the year/harvest 2016 (A) and 2017 (B), Dois Vizinhos, Paraná state, Brazil

In 2016, temperatures from May 8 to August 27 varied between 10 °C and 21 °C, with the highest average recorded between July 31 and August 6, while in 2017 temperatures above 20 °C, were observed only at the end of August, approximately a month after that of the previous year. In both the years, there were no mean temperatures below 10 °C. This fact is relevant because some cultivars require more hours of cold to overcome bud dormancy.

Precipitation was higher in 2016 in the period evaluated compared to 2017. In 2016, there were 14 instances of precipitation, with the rain volume in two of these periods close to 100 mm, whereas in 2017, the precipitation was reduced to eight instances with volumes not exceeding 55 mm.

In 2016, 185 hours below 7.2 °C and in 2017, 107 hours were recorded. Although, there were fewer hours of cold temperatures in 2017, the conditions of were more intense.

When the percentage of flowering of the 16 peach cultivars was evaluated, a correlation between the evaluated cultivars and the crops years (2016–2017) was observed (Table 1).

The average flowering rates for the cultivars Charme, Douradão, Granada, Bonão, and Eldorado were 63.53, 87.61, 62.58, 82.89, and 61.71%, respectively, in the year/harvest 2016, which were higher than those in the year/harvest 2017. In 2017, there was a was statistically significant difference in fruit set in the cultivars Rubimel, Leonense, Riograndense, Chimarrita, Regalo, Kampai, Fascínio, and Bonão, the fruit set rates were 51.71, 48.05, 63.81, 40.88, 66.60, 70.89, 45.95, and 54.44%, respectively.

Table 1
Average number of buds evaluated (n) and flowering rate (%) of 16 peach cultivars in the field in the 2016 and 2017 crop years in Dois Vizinhos, Paraná state, Brazil

Cultivar	2016 (n)	2017 (n)	Flowering (%)		Average
			2016*	2017	
Rubimel	52	99	84.07 aA	18.94 bB	46.48
Leonense	68	199	47.41 bA	40.35 aA	45.94
Coral	82	124	19.10 cB	35.96 aA	16.77
Marli	55	123	36.83 bA	42.63 aA	32.43
Charme	85	163	57.24 bA	30.22 aB	49.13
Riograndense	41	110	13.81 cB	28.73 aA	36.13
Douradão	58	119	61.06 bA	12.46 bB	62.24
Chimarrita	52	145	40.37 bA	28.27 aA	44.32
Regalo	89	129	7.12 dB	33.61 aA	38.00
Kampai	64	80	82.06 aA	48.47 aB	45.47
Fascínio	91	111	43.50 bA	40.01 aA	35.79
Zilli	77	171	82.57 aA	32.72 aB	36.63
Granada	34	108	58.57 bA	55.12 aA	41.15
BR-1	100	139	1.73 dA	5.06 cA	34.85
Bonão	53	73	85.94 aA	42.21 aB	68.66
Eldorado	51	120	45.44 bA	24.87 aB	47.69
Average	65.75	125.81	43.54	41.67	42.61
CV (%)	40.30		21.36		

*Averages followed by distinct letters, lowercase in the column and uppercase in the row, differ from each other by the Scott-Knott test at 5% significance (p ≤ 0.05).

The highest flowering rates in the year/harvest 2016 occurred in Charme, Douradão, Granada, Bonão, and Eldorado, with a range of 87.61% to 62.58%. For the year/harvest 2017, the fruit set rates were lower when compared to the rates of the previous year for the cultivars Rubimel, Leonense, Riograndense, Regalo, Kampai, Fascínio, and Bonão.

The Bonão cultivar showed a flowering rate above 50% in the two-year evaluation period, which was not observed with the other cultivars. The other cultivars revealed changes in the flowering rate between the two evaluated years. The Riograndense and Regalo cultivars presented fruit set of 9.41% and 8.45% in 2016, respectively. In 2017, Coral had 16.15% of fruit set and Granada showed 19.72%. These results may have been affected by some unfavorable environmental events that were not identified in the flowering period of these cultivars in 2016.

In 2017, temperatures showed less variation during the second half of July, which may have contributed to the difference in the flowering rates observed between 2016 and 2017.

Picolotto et al. (2009) evaluated the phenology and productivity of the Chimarrita cultivar on different rootstocks and found that in 2008, the high temperatures during the dormancy period damaged flowering that resulted in a large amount of dormant flower buds.

The consequence of insufficient and sporadic cold temperatures is limited flowering, and this leads to a decrease in fruit production (Scariotto, Citadin, Raseira, Sachet, & Pensa, 2013). Raseira, Pereira, & Carvalho (2014) described the importance of information regarding the climate for peach production in the southern region of the country.

According to Citadin, Raseira, Silva and Quezada (2003), flowering is influenced by the heat exposure after the dormancy period. Heat is required for the flower buds to begin opening until full flowering. However, for the vegetative buds, the hours of chill accumulation in the period of dormancy is more important for the opening of the yolks than the heat.

For the assessing the variations in the bud rate, the interaction between the tested cultivars and the year/harvest was also observed (Table 2).

Table 2
Average number of buds evaluated (n) and bud rate (%) of 16 peach cultivars in the field in the 2016 and 2017 crop years in Dois Vizinhos, Paraná state, Brazil

Cultivar	2016 (n)	2017 (n)	Bud rate (%)		Average
			2016*	2017	
Rubimel	58	77	28.40 bA*	25.36 bA	51.51
Leonense	70	94	10.02 bA	1.70 cA	43.88
Coral	67	79	52.53 aA	53.15 aA	27.53
Marli	65	88	48.69 aA	24.19 bA	39.73
Charme	79	97	62.84 aA	11.84 cB	43.73
Riograndense	45	86	0.00 cA	3.70 cA	21.27
Douradão	49	89	49.03 aA	23.73 bB	36.76
Chimarrita	52	90	66.85 aA	18.67 bB	34.32
Regalo	70	82	64.61 aA	20.32 bB	20.36
Kampai	62	72	65.20 aA	45.55 aA	65.27
Fascínio	66	72	51.12 aA	23.52 bA	41.76
Zilli	65	107	43.00 aA	18.06 bB	57.65
Granada	50	72	12.12 bA	10.59 cA	56.84
BR-1	79	88	75.70 aA	3.94 cB	3.40
Bonão	57	69	23.50 bA	35.07 aA	64.08
Eldorado	64	79	31.27 aA	6.37 cB	35.16
Average	62.37	83.81	47.93	32.98	40.20
CV (%)	14.85		18.01		

*Averages followed by distinct letters, lowercase in the column and uppercase in the row, differ from each other by the Scott-Knott test at 5% significance ($p \leq 0.05$).

In 2016, the recorded cold hours (185) were higher than in 2017, which led to a higher sprouting rate for 13 of the 16 cultivars. In 2017, only Coral, Riograndense, and Regalo showed increased sprouting rates.

In 2016, the cultivars with the highest sprouting rates were Rubimel, Kampai, Zilli, and Bonão (84.07, 82.06, 82.57, and 85.94%, respectively), followed by Charme, Douradão, and Granada, which exceeded 50% of sprouting.

For the year/harvest 2017, the lowest sprouting rates were in the cultivar BR-1 (5.06%), which required over 300 hours of cold, followed by Rubimel and Douradão. Despite being indicated for places with warmer climates requiring less than 100 hours of cold, the cultivar Douradão did not show satisfactory results in the period evaluated. Only Granada showed adequate performance in the two years/harvests evaluated, displaying a greater regularity of sprouting regardless of the winter conditions observed in Dois Vizinhos, Paraná state, Brazil.

The winter of 2016 had greater intensity and regularity of cold compared to the following year, with 185 and 107 hours below 7.2 °C, for 2016 and 2017, respectively. This favored the sprouting of several cultivars. Another relevant aspect was mentioned by Citadin et al. (2003), who described that chill accumulation is more important for the sprouting of vegetative buds than the need for heat.

The data show that the cultivars Leonense, Coral, Marli, Charme, Riograndense, Chimarrita, Regalo, Kampai, Fascinio, Zilli, Granada, Bonão, and Eldorado had the highest sprouting rates in 2017, which had a less intensive winter, despite being classified as requiring more than 250 hours of temperatures below 7.2 °C, These cultivars showed good results among the evaluated cultivars.

Anzanello & Lampugnani (2019) evaluated the need for cooling during the dormancy period in peach trees in the city of Veranópolis, Rio Grande do Sul, for the cultivars Pampeano and Eragil; the authors identified the need for 192 cold hours for Pampeano and 432 cold hours for Eragil. These authors confirmed the need for low temperatures to overcome dormancy in buds and flowering.

According to Petri and Herter (2004), the bud endodormancy of temperate fruit trees is only broken when 50% or more of the vegetative buds have sprouted. Thus, the winter cold in Dois Vizinhos, especially during mild winter years (e.g., 2017), is insufficient for the commercial cultivation of most peach cultivars evaluated in this study.

For the variable fruit set, correlation was also observed between the tested cultivars and the year/harvest. In 2016, the average fruit set (42.81%) was twice as that observed in the following year (20.36%), showing that the environmental conditions of the 2016 harvest year were more favorable for the fruiting of most peach cultivars (Table 3). These data corroborate the data obtained by Nava, Kurschner and Paulus (2020), who observed that the productivity of most peach cultivars cultivated in the same experimental study area was higher in 2016 because of improved environmental conditions, especially the increased winter cold, with emphasis on the cultivars Bonão, Charme, and Eldorado.

The highest fruit set rates in 2016 were obtained in the cultivars, Coral, Marli, Charme, Douradão, Chimarrita, Regalo, Kampai, Fascinio, Zilli, BR -1, and Eldorado. The Riograndense cultivar had the lowest rate (null), which can be explained by the low flowering in this cultivar (8.45%) in 2016. In 2017, the cultivars, Coral and Kampai showed the superior results, and Leonense, Charme, Riograndense, Granada, BR-1, and Eldorado had the most inferior rates (Table 3).

An important factor for the low fruiting rates for most cultivars in 2017 was the short winter period (107 cold hours), as well as the scarcity of rain between the flowering period until fruit set (mid-June to late July).

In 2017, the occurrence of higher average temperatures in June and July than in the previous year, as well as low temperatures and frost formation in mid-July, also contributed to the low fruiting rates that occurred in that year.

When studying the cultivar Granada, Nava et al. (2011) reported that temperatures above 25 °C during the day in pre-flowering and flowering periods significantly reduced the fruit set rates by degenerating the pollen grains and delaying the development of the embryo sac, thus disrupting the fertilization of the flowers.

Table 3

Average number of flowers evaluated (n) and fruit set (%) of 16 peach cultivars in the field in the 2016 and 2017 crop years in Dois Vizinhos, Paraná state, Brazil

Cultivar	2016 (n)	2017 (n)	Fruit set (%)		Average
			2016*	2017	
Rubimel	19	51	28.40 bA*	25.36 bA	26.88
Leonense	29	73	10.02 bA	1.70 cA	5.86
Coral	14	20	52.53 aA	53.15 aA	52.84
Marli	16	42	48.69 aA	24.19 bA	36.44
Charme	55	57	62.84 aA	11.84 cB	37.34
Riograndense	4	67	0.00 cA	3.70 cA	1.85
Douradão	50	44	49.03 aA	23.73 bB	36.38
Chimarrita	25	59	66.85 aA	18.67 bB	42.76
Regalo	9	88	64.61 aA	20.32 bB	42.47
Kampai	13	53	65.20 aA	45.55 aA	55.37
Fascínio	23	51	51.12 aA	23.52 bA	37.32
Zilli	36	45	43.00 aA	18.06 bB	30.53
Granada	20	21	12.12 bA	10.59 cA	11.35
BR-1	44	34	75.70 aA	3.94 cB	39.82
Bonão	44	39	23.50 bA	35.07 aA	29.28
Eldorado	30	42	31.27 aA	6.37 cB	18.82
Average	26.94	49.12	42.81	20.36	31.58
CV (%)	19.75		30.80		

*Averages followed by distinct letters, lowercase in the column and uppercase in the row, differ from each other by the Scott-Knott test at 5% significance ($p \leq 0.05$).

Modesto et al. (2014) evaluated the percentage of vegetative, flowering, and fruiting buds of the cultivars Turmalina, Precocinho, CP 951-C, Conserva 693, and Oro Azteca in the city of Botucatu, in the state of São Paulo. The authors observed that the cultivar Oro Azteca presented 84.50% of vegetative buds and 25.30% of flowering buds, and thus an effective fructification of 4.20 was observed. In this study, in relation to the highest percentage of flowering buds, the cultivar Precocinho revealed 26.30% of flowering buds with the highest fruit set among the evaluated cultivars. The cultivar Conserva 693 showed the lowest levels for these three variables, with 32.30% of vegetative buds, 8.90% of flowering buds, and a 0.70 fruit set.

Conclusions

The climatic conditions in the municipality of Dois Vizinhos, Paraná state, Brazil, promoted the highest rates of sprouting and fruit set in the year/harvest 2016.

Cultivar Bonão showed greater flowering intensity and regularity in the crop years evaluated (2016 and 2017).

The Coral and Kampai cultivars presented fruit sets with greater intensities and regularities compared to the other cultivars evaluated for the climate condition of the evaluated location.

The Riograndense cultivar showed the greatest irregularity in flowering and fruit production.

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