Phenology of advanced selections of low-chilling peach trees in Urussanga, state of Santa Catarina[1]

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ABSTRACT

The objective of this study was to evaluate the influence of the environment and the genetic factor on the the phenology of 16 advanced selections of peachtrees in the municipality of Urussanga, state of Santa Catarina. The experiment was conducted in two areas (360 m and 220 m above sea level) in 2017, 2018, and 2019 harvests. The selections are part of the EPAGRI fruit breeding program. The dates of beginning, full, and end of flowering and budding, percentage of flowering, budding and effective fructification were determined. The standard model (number of hours with temperatures below 7.2 °C) was not the most suitable. Full flowering was anticipated by five days, on average over three years, at the highest altitude due to the greater accumulation of cold. The 16 selections were classified into three groups: early (harvest in October), medium (harvest in November), and late (harvest in December). It is concluded that the environment and the genetic factor influence the phenology of advanced peach selections. Being the first, it influences the periods of flowering and budding and the percentages of flowering, budding and effective fruiting. The second with emphasis the maturation cycle and the harvest period.

Keywords: *Prunus persica* (L.) Batsch; fruit breeding; climate adaptation; flowering; harvest.

INTRODUCTION

Climate adaptation is one of the main features investigated in genetic improvement programs as a way for crops to express their maximum potential. Peach needs specific climatic conditions for its adequate development. Thus, several regional climatic factors interfere in the development of plants, such as the accumulation of cold hours, temperature, radiation, frequency and intensity of winds, and water availability (Monet & Bassi, 2008).

These environmental factors influence the phenology of plants by interfering with the adaptability of a genotype in a particular region, as the requirements for winter cold and heat vary among the different peach genotypes. This variation interferes in the productive cycle and the phenological stages of flowering, budding, and ripening of each cultivar. Knowing this information intrinsic to each cultivar enables planning of the pruning period, phytosanitary treatments, an estimate of the risk of hail and frost, and predicting the harvest period (Nava *et al.*, 2009).

Those are the reasons why, in the final stages of the breeding program, the genotypes are tested at different locations in the region of interest, to observe their behavior under different soil and climatic conditions.

Thus, it is necessary to study the phenology of genotypes evaluated in a breeding program. This information

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bank will play a fundamental role as a basis for decisions on which selection will have the potential to become a cultivar.

Therefore, the objective of this study was to evaluate the influence of the environment and the genetic factor on the the phenology of 16 advanced selections of peach of low chilling necessity in the municipality of Urussanga, state of Santa Catarina.

MATERIAL AND METHODS

This experiment in particular is the final phase of the evaluation of advanced selections of peach trees in the fruit breeding program of the Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI). The selection validation phase is carried out in orchards of farmers in the region of interest to track these genotypes in different soil and climate conditions and management practices. Thus, the study was conducted in two experimental areas located in the municipality of Urussanga, in the state of Santa Catarina. One area is located at 220m above sea level at coordinates 28°32'53.74"S and 49°19'52.84"W and the second is at 360m altitude located at 28°27'51.80"S and 49°15'18.96"W. Both areas are commercial peach tree farms.

The climate in the region is classified, according to Köppen (1936), as humid mesothermal with regularly well-distributed rainfall and hot summer (Cfa). The average temperature of the coldest month is within the range of 13 to 15 ºC, the normal average temperature ranges from 17.0 to 19.3 ºC (Dufloth *et al.*, 2005). The normal total annual rainfall may vary from 1,220 to 1,660 mm. The average number of chill hours below 7.2 ºC in Urussanga during the entire winter period is 234 (Pola *et al.*, 2016a).

The 16 advanced selections were planted in August 2014 at 6x1 m spacing, with the plants conducted in the "Y" system. For each selection, three seedlings were planted. The rootstock used was 'Okinawa', which is the most used in the region.

Both areas received the same management to avoid any influence on the results. Thus, a standard was defined for the management practices adopted in the experiment regarding soil management, fertilization, pruning, phytosanitary treatments, and thinning, according to the norms of integrated peach tree production, described by Fachinello *et al.* (2003).

Over the experimental period (January 2017 to December 2019), average hourly temperature data in °C were monitored. In the lower altitude area, a meteorological station was installed with an AKSO® datalogger placed in a wooden shelter at 1.5 m from the ground inside the orchard. On the other hand, in the higher altitude area, a conventional Campbell® station was installed.

For the calculation of the accumulation of cold during the endodormancy period, two models were considered: chill hours (CH) below or equal to 7.2 °C (Weinberger, 1950), which was considered the standard model, and the one below 13 °C (Citadin *et al.*, 2002) was the alternative model. The peach endodormancy period was considered between April (when the natural fall of most leaves) and June 15 (the date stipulated by Pola *et al.*, 2022) for the end of endodormancy of peach trees in the experimental site.

To calculate the heat accumulation to overcome echodormancy, the method of degree-days or heat units denominated "Growing Degree Hour Celsius" (GDH °C), defined as one hour at a temperature of 1 °C above the peach tree's base temperature of 4.5 °C. The unit of heat (GDH °C) was calculated by subtracting 4.5 from each hourly temperature between 4.5 °C and 25 °C, so the highest accumulation for an hour is 20.5 GDH °C, while there is no accumulation of heat at temperatures equal to or below 4.5 °C. The sum of these heat units indicates the degree-days (Richardson *et al.*, 1975). The period used in this experiment was from June 16 until the date when flowering began. So, the average date of the beginning of flowering of the 16 peach tree selections was considered.

Phenology was controlled by selecting four year-branches (two on each side of the plant) in which two of them were at 1.5 m above the ground and two at 1.8 m, with 50 cm in length and over 4 mm in diameter.

In this branch plot, the total number of flowering buds and vegetative buds in the dormancy phase was counted. As flowering started, the number of open flowers, buds, and fruits was quantified three times a week until the phase that precedes thinning.

Using the total value of flowering and vegetative buds and the quantification of flowers, buds, and fruits on each evaluation date was possible to determine each phenological stage. The average value of the phenological stage (PS) of the plant in each evaluation was obtained using the following equation: . Where NF or NV is the number of flowering or vegetative buds to calculate the percentage of flowering and vegetation, respectively, and TNB is the total number of buds. Thus, the following were determined: the beginning of flowering, when 5% of the flowers were open;

full flowering, when 50% of the flowers are open; and the end of flowering, when 90% of the petals had fallen.

The budding stages were considered the beginning, full, and end of budding when, 5%, 50%, and 90% of the vegetative buds sprouted, respectively.

The flowering period (difference in days of the flowering start and end date), and the percentages of budding, flowering, and effective fruiting were also determined. Effective fruitification was calculated through the ratio between the total number of open flowers and the number of fixed fruits (with 5 mm in diameter), after a natural fall, on marked branches.

The fruits, at the ripening point (by visually determining the color of the skin of the fruit and light pressure with the hands to detect the firmness of the fruit), were harvested every three days, counting the total number of fruits per plant and the average fruit mass. These evaluations were used to determine the harvest period of each selection and the production throughout the harvest, enabling to determine the beginning, the full, and the end of the harvest where the full harvest is considered with 50% of the fruits already harvested. The fruit ripening cycle was determined, expressed in days, considering the period from full flowering to full harvest.

The experimental design adopted in this experiment was the randomized block with split-plotsin a 2x16x3 factorial scheme (two locations, 16 selections and three years of evaluation) with three replications, where four branches of a plant make up the plot.

The data on the percentage of effective fruiting, flowering, and budding flowering period (days) and fruit ripening cycle (days) was first submitted to a normal distribution analysis using the Shapiro Wilk method. In this analysis, all percentage data showed a p-value less than 0.05. Thus, the percentage data were transformed by the equation . And the data expressed in days were transformed from the equation.

The data transformed were subjected to an analysis of variance (ANOVA) and, when significant, a comparison of means was carried out using the Scott-Knott test, also at 5% of significance using the statistical program SISVAR. For the presentation of the analysis of the data, they were again transformed for a better understanding of the results and their interpretation.

The beginning, full and end dates of flowering and harvesting were submitted to a descriptive analysis.

A correlation was also performed using Pearson's method at 5% significance between the characteristics of full harvest date and fruit ripening cycle, to observe whether or not these two variables were correlated.

RESULTS AND DISCUSSION

A difference was found between the years and between the areas evaluated for both chill quantification models (Table 1). The higher altitude area, at 360 m above sea level, had a greater accumulation of chill in the three years of evaluation, for both models (CH below 7.2 or 13 °C) in relation to the lower altitude, except in 2019, because in both areas there was no difference in the accumulated cold hours below 7.2 °C. Despite being located in the same areas in the same municipality of Urussanga, they have different microclimates, greatly influenced by the altitude of the places.

Among the three years of evaluation, regardless of the area evaluated, 2018 was the year with the highest chill accumulation, followed by 2017 and finally 2019 (Table 1). These differences between the years of cultivation influence the quality of budding and flowering and, consequently, the production of fruits. The importance of selecting genotypes adapted to the conditions of temperature fluctuations over the years, which is very frequent in the southern region of Brazil, is highlighted.

Table 1: Chill accumulation considering the models below 7.2 and 13 °C in April, May, and the first fortnight of June and accumulated heat (GDH °C) from the second fortnight of June until the beginning of flowering (average date of 16 peach tree selections) in 2017, 2018 and 2019, in the two experimental areas: 360 m altitude and 220 m. Urussanga, SC, 2023

Model	2017		2018		2019	
	360 m	220 m	360 m	220 m	360 m	220 m
HF ≤ 7.2 °C	30	10	74	51	0	0
HF < 13 °C	391	185	439	315	270	141
GDH °C	6587	8274	8762	9630	10180	11078

A difference was found between the tested models. The year 2019 stands out as there was no accumulation of cold over this year when considering the model of chill hours below 7.2 °C.

Several models quantify the chill during the endodormancy period, one of them, with the hours below 7.2 ºC is still the most used in the study of the most diverse crops. However, for subtropical regions, it would not be suitable, as it does not effectively represent the overcoming of dormancy of species adapted to milder winters (Chavarria *et al.*, 2009). Therefore, the models that use milder temperatures, such as 12 or 13 °C, are more suitable for these conditions (Citadin *et al.*, 2002).

The accumulation of heat was lower in the area at 360 m of altitude in relation to the area at 220 m of altitude, in the three years of evaluation (Table 1). In addition, it is noteworthy that among the years evaluated, regardless of the area, 2019 had the highest accumulation of heat, followed by 2018 and finally 2017. This means that in 2019 the peach tree selections needed more heat to overcome echodormancy.

Couvillon & Erez (1985) observed that the heat requirement is not specific and that flowering dates are determined by the amount of cold to which the species were exposed. When productive branches of apple, plum, peach, and pear trees are exposed to a greater amount of cold, it reduces the number of GDH ºC necessary for flowering, that is, it reduces the need for heat to overcome echodormancy.

This statement is in agreement with the data in Table 1, nevertheless, in the area of higher altitude, there was a greater accumulation of chill, and the peach tree selections needed less accumulation of heat to overcome echodormancy.

Figure 1 shows that there was a difference between the years and the different altitudes regarding the flowering and budding period with the beginning, full and end dates. In general, there was an anticipation of the beginning and full flowering dates in the higher altitude area, in relation to the lower altitude, except in 2018. As for the dates of the end of flowering, no difference was observed between the areas in the three evaluated years.

For the beginning of flowering, the years 2017 and 2018 did not differ from each other, with their earlier dates compared to 2019. As for the dates of full and end of flowering, regardless of the evaluated location, anticipation occurred in the year 2017, followed by 2018, and finally 2019. The results in Figure 1 demonstrate a strong influence of the environmental factors of the areas and the years evaluated in the flowering season of the peach tree selections.

Comparing the table 1 and figure 1, the year 2019 had the lowest sum of cold hours and flowered later. However, 2018, which had the highest accumulation of cold hours, was not the one with the most anticipated flowering. Other factors are likely to have influenced the flowering dates this year.

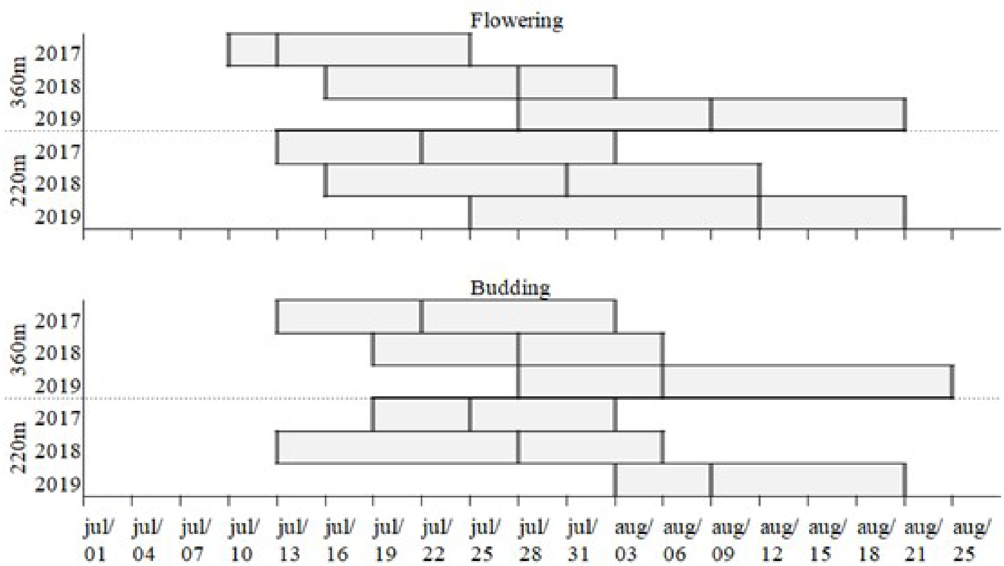

Figure 1: Average period of flowering and budding (beginning, full and end) of advanced peach tree selections in the three years evaluated (2017, 2018 and 2019) in two experimental areas (360m and 220m above sea level). Urussanga, SC, 2023.

According to Williams (1965), other factors besides the temperature influence the flowering date, such as early leaf fall in the summer due to phytosanitary problems, water shortage during the dormancy period, and cloudy and rainy days during the pre-and flowering periods.

Regardless of the location, the years 2017 and 2018 did not differ and had earlier budding compared to 2019. Except for full budding in the higher altitude area, where anticipation was obtained in 2017, followed by 2018, and finally 2019.

Opposite to flowering, buddings were very similar between locations, where the date of full budding was earlier in the higher altitude area in 2017 and 2019 and did not differ in 2018 in the lower altitude area. For the beginning of budding, in 2017 and 2019, the higher altitude area had earlier dates and in 2018 the lower altitude area had earlier budding. The dates of the end of budding did not differ between the sites in 2017 and 2018, however, in 2019, the area of lower altitude obtained anticipation of the end of the budding in relation to the area of higher altitude.

The comparison between the dates of flowering and budding showed that 2018 stands out, where the dates were very close in the area of higher altitude, or even the budding started before flowering in the area of lower altitude. Flowering and vegetative buds have different cold and heat requirements, in which the vegetative ones need a greater accumulation of cold to overcome dormancy (Biassi & Monet, 2008). This is one manner of prevention shown by the deciduous species so that the vegetative buds sprout later to avoid possible damage by low temperatures or frosts, which normally occur at the beginning of winter. In addition, it should occur before flowering and soon after budding as this would avoid energy competition by the plant, resulting in uniform flowering and adequate effective fruiting. However, in some cases, due to environmental or genetic factors, budding may occur together or even before the beginning of flowering (Nava *et al.*, 2009).

In 2018, the cold required by the selections during dormancy had been reached earlier, demanding later an accumulation of heat, which is differentiated between flowering and vegetative buds. According to Citadin *et al.* (2003), the selection of individuals with a high heat requirement for flowering tends to delay flowering, but without delaying the budding season at the same intensity.

Thus, care must be taken with the thermal needs of the selections: when they have a low need for cold and heat and are planted in regions such as the one of this experiment, which has years with a low sum of CH. In this case, sproutings may be early, which can lead to great losses and frost damage and impair flowering and fruiting.

Genes related to the cold and heat requirements play a very similar degree of influence in the peach flowering season, however, in the vegetative buds, the influence of genes that control the need for cold is higher, indicating that the genetic control for the heat need differs for floral and vegetative buds (Citadin *et al.*, 2002). Therefore, the behavior of some cultivars that sprout before flowering is explained by the assumption that they have a greater heat need for flowering than for budding. Thus, the selection of cultivars with a low need for cold for sprouting and flowering, but with a high need for heat, can be an interesting strategy for regions with a subtropical climate.

There were no significant differences in flowering and budding dates between selections. The need for cold and heat to overcome dormancy is a main feature in the objectives of the peach fruit breeding program for regions with mild winters. Since the selection process, during the phases of the program, for this characteristic, is well intensified. Thus, the advanced selections present low variability for this characteristic.

For most of the assessed phenological parameters, a difference was observed between environments and years; thus, weather conditions affect the flowering, fructification, and budding of peach tree selections There was a difference between the peach tree genotypes evaluated for these parameters, demonstrating that the genetic factor also influences (Table 2).

Regarding the length of flowering, the location did not influence it; however, between the assessed years, a statistically but very small difference was found (Table 2). The year 2019 presented the longest period (25.6 days), followed by 2018 (23.94 days) and a shorter period in 2017 (19.28 days). The year 2019 had less cold accumulation during the dormancy period (Table 1) and flowering occurred later in relation to the other years (Figure 1), therefore, the flowering buds bloomed more slowly, extending the period. Among the selections, the flowering period ranged from 17.83 (sel. 0256) to 30.17 (sel. 1363), with a difference of 12.34 days.

Both short and extensive flowering period has some advantages and disadvantages. The shorter flowering period reduces the costs of phytosanitary treatment to control diseases such as brown rot on flowers and influences the harvest period, inducing a more concentrated crop of

Table 2: Flowering period (days) and flowering, effective fructification and budding percentage of peach selections in the three experimental areas (360m and 220m above sea level) in the three evaluation years (2017, 2018, and 2019). Urussanga, SC, 2023

Model	Flowering period (days)		% Flowering		% Effective fructification		% Budding	
360m	22.77	ns*	79.9	a	41.05	a	85.35	a
220m	23.1		54.19	b	38.81	b	83.43	b
CV (%)	11.23		9.25		16.33		9.18	
2017	19.28	c	66.94	b	44.83	a	85,16	a
2018	23.94	b	66.77	b	31.54	c	82,97	b
2019	25.6	a	67.39	a	43.39	b	85,03	a
CV (%)	12.11		10.89		13.18		8,97	
3174	22.5	d	60.94	g	36,00	e	85.86	d
0184	23.83	c	65.88	d	38.66	d	82.91	g
0194	22,00	d	63.07	e	40.83	d	82.25	g
0256	17.83	f	60.41	f	30.05	f	86.68	d
0356	25.33	b	72.3	b	25.71	g	86.21	d
0374	24,00	b	68.85	b	43.63	c	85.54	e
0381	26.83	b	71.39	b	51.88	a	87.67	c
0391	23.67	c	68.06	c	49.38	a	84.78	f
0574	22.17	d	78.37	a	42.74	c	88.68	b
0581	18.33	f	72,00	b	25.13	g	86.85	d
0791	19.83	e	65.4	d	46.7	b	85.45	e
0891	19.33	e	62.2	e	32.98	f	79.87	h
1174	22.33	d	60.67	f	40.41	d	85.32	e
2874	25,00	b	55.33	g	50.66	a	64.92	i
0563	23.83	c	69.82	b	41.34	c	87.17	c
1363	30.17	a	77.9	a	42.79	c	90.03	a
CV(%)	9.33		12.56		15.67		10.11	

Note: different letters indicate statistical difference by the test of Scott-Knott at 5% of significance. ns: non-significant.

the same genotype, reducing labor costs, and facilitating logistics. However, shorter flowering periods may harm fructification if it occurs during cloudy and rainy periods (Williams, 1965). If any environmental adversity occurs during flowering, the more widely spaced blooms may suffer less damage and thus not interfere so much with fruit production (Bassi & Monet, 2008). Thus, greater variability between genotypes is interesting in a breeding program, as it presents different options for different foci.

Regarding flowering percentage, there was a statistical difference between the locations, where the higher altitude area showed a higher value (79.9%) than the lower altitude area (54.19%) (Table 2). Several factors may influence the flowering percentage, such as climatic factors such as temperature during the winter cold, the temperature during flowering, precipitation, and incident radiation; management factors such as plant nutrition, among others (Bassi & Monet, 2008). Thus, one or more factors may have influenced this difference.

Among the evaluated years, despite the statistical difference, the percentage of flowering among the three years was very similar, between 66.77%, 66.94%, and 67.39%.

The over-intense flowering is advantageous in case some factors negatively influence fructification, such as the incidence of diseases, rainy periods, and late frosts; in these cases, there is less damage because of the large number of flowers. However, intense blooms coinciding with high fruiting provide a large amount of fruit, which results in greater labor for thinning. Therefore, the ideal would be to obtain balanced flowering, minimizing the practice of thinning, which currently limits the expansion of the crop.

Similar to flowering, a statistical difference was found in the percentage of fruiting between the locations, where the area with the highest altitude also presented a higher value (41.05%) than the one with the lowest altitude (38.81%). These results were most likely influenced by the microclimate of each site, with emphasis on the difference in the sum of cold hours during the winter period.

A statistical difference was observed for the fruit set between the years, which was higher in 2017 (44.83%), followed by 2019 (43.39%), and finally 2018 (31.54%).

Inadequate climatic conditions during the flowering period can also influence fruit sets by affecting pollination, pollen tube growth, and ovule fertility (Williams, 1965). Rain and high relative humidity are harmful as they facilitate the occurrence of diseases in flowers, especially brown rot (Gradziel & Weinbaum, 1999).

Effective fruiting ranged from 25.13 (sel. 0581) to 51.88% (sel. 0381) among selections (Table 2). If a high flowering rate coincides with a high fruit setting rate, this implies a higher intensity of thinning and, consequently, higher labor costs. As an example, selection 0381 had a high flowering percentage of 71.39 and an effective fruiting of 51.88%, that is, it resulted in a high rate of fixation, which resulted in more intense thinning. On the other hand, selection 2874, which presented a low flowering 55.33%, resulted in good effective fruiting of 50.66%, indicating that half of the buds that flowered became fruits, causing a greater balance of the plant and less interference of thinning.

The peach tree generally has high effective fruiting rates, provided that flowering coincides with sunny, mild, and dry days, ranging from 13.5 to 83.2% (Monet & Bassi, 2008).

Knowledge of the fruiting process of a species, as well as other interrelated factors, is extremely important in the discernment of some cultural practices, such as pruning, fruit thinning, use of fertilizers, and growth regulators. Harvest estimates, as well as the final fruit size, are closely related to the fruiting characteristics of the species and the fruit thinning intensity (Nava *et al.*, 2009).

Finally, the budding percentage showed a statistical difference between the two areas, with 85.35% in the area of 360m of altitude and 83.43% in the area of 220m of altitude. There was no statistical difference between 2017 and 2019 with 85.16 and 85.03%, respectively, both differing from 2018, which presented 82.97% of budding. Among the sixteen advanced selections, sprouting ranged from 64.92 (sel. 2874) to 90.03% (sel. 1363) with an average of 84.39%, considered reasonable by many authors. All showed adequate budding percentage, which is essential for the establishment of vegetation in plants and also as a source of energy for fruit development.

Pearson's correlation between full flowering date and fruit ripening cycle was not significant ($p > 0.05$). It was observed that selections 3174 and 1363, with a long cycle (above 125 days), showed earlier flowering than selections 2874, 0391, and 0381, with a short cycle (from 79 to 94 days), which were those that flowered later than the others, regardless of year or location. However, the mid-cycle selections did not show a pattern, which did not result in the significance of the correlation.

However, some authors point to a relationship between the ripening cycle and the date of full bloom. Pola *et al.* (2016b) developed regression models to predict the length of the period between flowering and harvest in Urussanga, Santa Catarina, indicating that the earlier the flowering date, the longer the cycle length.

With an outcome of 0.925 reliability, the fruit ripening cycle and the full harvest date showed a positive correlation, that is, the longer the cycle, the later the harvest date, for example, among the 16 advanced selections, 2874, 0391, and 0381 are harvested in October, with a ripening cycle between 79 and 94 days; some of them with harvest in November (selections 0256, 0374, 0574, 1174, 0184 and 0194), which vary the cycle from 107 to 115 days and selections 3174 and 1363, with harvest in December have a longer cycle of 133 days.

This correlation may be important for the breeding program, as its objective is to investigate cultivars with an earlier, medium, or late cycle. That is, the characteristic size of the fruit ripening cycle is a strong indication of the harvest period that such genotype will present.

Selections such as 2874, 0391, 0381, and 0356 showed very interesting characteristics, because, among the 16 genotypes, they are those that flower later and are harvested earlier. Such characteristics may result in flowering in periods with less incidence of frost because they are selections with a greater need for cold. Also, they can have shorter cycles, therefore, phytosanitary treatments in the fruits will cost less and as they are early selections with harvest in the last fortnight of October, they become important, as they promote the search for better commercialization prices due to the lower supply.

No statistical difference was found between the experimental areas for the average ripening cycles of the advanced peach tree selection as the area with the highest altitude presented an average of 109.9 days and 109.78 days for the one with the lowest altitude. Among the evaluated years, the following differences were observed: 2018 had 110.87 days, followed by 2019 with 110.03 and 2017 with 108.63. This may indicate that the environment, either the location or the climatic factors of each year, has little influence on the length of the cycle of peach selections.

The fruit ripening cycle is genetically controlled but it may vary with the environmental conditions of each year (Marra *et al.*, 2002). Several works have shown that the length of this phase is related to the temperatures that occur soon after flowering. Some authors particularly relate the temperatures that occur up to 30 days after flowering to the fruit development cycle, stating that the higher the temperature in this period, the shorter the cycle (Tombesi *et al.*, 2010).

The date of full harvest also showed no statistical difference regarding the experimental areas, where they both presented the average on the same day, November 11. However, the comparison between the years showed a statistical difference, where 2018 had a later harvest, approximately on November 15, not differing from 2019, which had an average harvest on November 12, but both differing from 2017, which presented an earlier harvest, November 6th, approximately.

Souza *et al.* (2019) evaluated the influence of the temperature on the cultivation of four peach cultivars (Tropical, Aurora-2, Ouro Mel-4, and Biuti) under subtropical conditions, and highlighted that temperature greatly influenced the development of fruits of each genotype, with a particular thermal requirement to complete the reproductive cycle in each material.

Thus, in the previous results, a strong relationship between the characteristics of the fruit ripening cycle and the harvest period of the peach tree selections is observed, where three groups of fruit maturation stood out (Table 3):

- Selections 2874, 0391, 0381, and 0356 are considered early, with a harvest period concentrated in October. These selections had an average cycle length of 94.21 days.
- Selections 0256, 0574, 0891, 0374, 0194, 1174, 0184, and 0563 are classified as median, as their harvest is concentrated in November and the average fruit ripening cycle is 110.42 days.
- Selections 0581, 0791, 3174, and 1363 are considered late, with harvest in December and the average period from fruit development to harvest is 125.22 days.

This classification and separation are fundamental in a breeding program. Therefore, it must be taken into account that the objectives of each period of the harvest are different and the selections must be compared within the groups and not among all.

It is observed how much the environment influences the phenology of the peach tree, therefore, crucial care in breeding programs is to test the behavior of genotypes under different conditions, so that the decision-making indicated for a certain region is reliable. That is why climate

Table 3: Fruit ripening cycle (days) and the harvest period of advanced peach tree selections. Urussanga, SC, 2023

Sel.	Cycle (days)		Harvest dates																
			10/ Oct	15/ Oct	20/ Oct	25/ Oct	30/ Oct	04/ Nov	09/ Nov	14/ Nov	19/ Nov	24/ Nov	29/ Nov	04/ Dec	09/ Dec	14/ Dec	19/ Dec	24/ Dec	29/ Dec
2874	79.17	g																	
0391	89.84	f																	
0381	94.58	f																	
0356	109.27	d																	
0256	110.61	c																	
0574	111.00	c																	
0891	102.88	e																	
0374	112.78	c																	
0194	107.11	d																	
1174	112.44	c																	
0184	110.55	c																	
0563	116.00	b																	
0581	115.11	b																	
0791	119.33	b																	
3174	133.39	a																	
1363	133.05	a																	
CV (%)	8.16		EARLY					MIDIAN						LATE					

Note: different letters indicate statistical difference by the test of Scott-Knott at 5% of significance. ns: non-significant. Light gray indicates harvest period and dark gray indicates full harvest.

adaptation is the main objective pursued as it is from the level of adaptation that the maximum productive potential of the crop is guaranteed.

Finally, with the knowledge of the climatic characteristics of the region of interest in the program, it is possible to extrapolate the indication of cultivars released to other places that present similar conditions. This enables to expand the crop to other regions with elite genotypes that show adaptation combined with productivity and fruit quality.

CONCLUSIONS

It is concluded that the environment and the genetic factor influence the phenology of advanced peach selections. Being the first, it influences the periods of flowering and budding and the percentages of flowering, budding and effective fruiting. The second highlights the maturation cycle and the harvest period.

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REFERENCES

Bassi D & Monet R (2008) Botany and Taxonomy. In: Layne R & Bassi D (Ed.) The peach: botany, production and uses. 7ª ed., USA, Editora Cambridge, p 01-36.

Chavarria G, Herter FG, Raseira M do CB, Rodrigues AC, Reisser C & Da Silva JB (2009) Mild temperatures on bud breaking dormancy in peaches. Ciência Rural, Santa Maria, 39:2016-2021.

Citadin I, Raseira M do CB, Herter FG & Silveira CAP (2002) Avaliação da necessidade de frio em pessegueiro. Revista Brasileira de Fruticultura, 24:703-706.

Citadin I, Raseira M do CB, Quezada AC & Da Silva JB (2003) Herdabilidade da necessidade de calor para a antese e brotação em pessegueiro. Revista Brasileira de Fruticultura, 25:118-123.

Couvillon GA & Erez A (1985) Influence of prolonged exposure to chilling temperatures on bud break and heat requirement for bloom of several fruit species. Journal of the American Society for Horticultural Science, 110:47-50.

Dufloth JH, Cortina N, Veiga M & Mior LC (2005) Estudos básicos regionais de Santa Catarina. In: Programa Nacional de Fortalecimento da Agricultura Familiar, Florianópolis. Proceedings, EPAGRI. CD-ROM.

Fachinello JC, Tibola CS, Vicenzi M, Parisotto E, Picolotto L & Mattos MLT (2003) Produção integrada de pêssegos: três anos de experiência na região de Pelotas, RS. Revista Brasileira de Fruticultura, 25:256-258.

Gradziel TM & Weinbaum SA (1999) High relative humidity reduces anther dehiscence in apricot, peach, and almond. HortScience, 34:322-325.

Köppen W (1936) Das geographische system der klimate. In: Köppen W & Geiger R (Eds.) Handbuch der klimatologie. Berlin, Gebruder Borntraeger. p.01-44.

Marra FP, Inglese P, Dejong TM & Johnson RS (2002) Thermal time requirement and harvest time forecast for peach cultivars with different fruit development periods. Acta Horticulturae, 592:523-529.

Monet R & Bassi D (2008) Classical Genetics and Breeding. In: Layne R & Bassi D (Eds.) The peach: botany, production and uses. USA, Cambridge University Press. p.61-84.

Nava GA, Marodin GAB & Santos RP (2009) Reprodução do pessegueiro: efeito genético, ambiental e de manejo das plantas. Revista Brasileira de Fruticultura, 31:1218-1233.

Pola AC, Della Bruna E, Back AJ & Moreto AL (2016a) Estimativa da duração da fase florescimento-colheita em variedades de pessegueiro em Urussanga, SC. Revista Agropecuária Catarinense, 29:68-73.

Pola AC, Della Bruna E, Back AJ & Moreto AL (2016b) Influence of different temperature levels on the date of full bloom of peach varieties in subtropical climate. Revista Brasileira de Fruticultura, 38:e240.

Pola AC, Della Bruna E, Petry HB & Moreto AL (2022) Dormancy dynamics of reproductive and vegetative peach buds in a subtropical climate. Horticultura Argentina, 41:20-33.

Richardson EA, Seeley SD, Walker Anderson JL & Ashcroft GL (1975) Pheno-climatography of Spring Peach Bud Development. HortScience, 10:236-237.

Souza F, Alves E, Pio R, Castro E, Reighard G, Freire AI & Mayer NA (2019) Influence of Temperature on the Development of Peach Fruit in a Subtropical Climate Region. Agronomy, 9:01-10.

Tombesi S, Scalia R, Connelll J, Lampinen B & Dejong TM (2010) Fruit development in almond is influenced by early spring temperatures in California. The Journal of Horticultural Science and Biotechnology, 85:317-322.

Weinberger JH (1950) Chilling Requirements of Peach Varieties. Proceedings of American Society for Horticultural Science, 56:122-128.

Williams RR (1965) The effect of summer nitrogen applications on the quality of appleblossom. Journal of the Horticultural Science, 40:31-41.