https://doi.org/10.1590/1678-4499.20250195

BASIC AREA
Article

Estimating chill and heat requirement for peach flowering and harvesting season in tropical production areas

Graciela da Rocha Sobierajski[1*], Gabriel Constantino Blain[2], Newton Alex Mayer[3]

1. Instituto Agronômico de Campinas – Divisão Avançada de Pesquisa e Desenvolvimento de Frutas – Jundiaí, (SP), Brazil.
2. Instituto Agronômico de Campinas – Divisão de Pesquisa e Desenvolvimento de Biossistemas Agrícolas e Pós-Colheita – Campinas (SP), Brazil.
3. Empresa Brasileira de Pesquisa Agropecuária – Clima Temperado – Pelotas (RS), Brazil.

Received: Sep. 22, 2025 | **Accepted:** Jan. 5, 2026

Section Editor: Patrícia Cia

***Corresponding author:** graciela.rocha@sp.gov.br

How to cite: Sobierajski, G. R., Blain, G. C. and Mayer, N. A. (2026). Estimating chill and heat requirement for peach flowering and harvesting season in tropical production areas. Bragantia, 85, e20250195. https://doi.org/10.1590/1678-4499.20250195

ABSTRACT: Low air temperature during the dormancy period promotes uniform flowering in peach trees, while the heat after the full bloom is necessary for fruit development. Rootstock cultivars affect the timing of scion phenological stages, either advancing or delaying their occurrence from bud break to harvest. Given the expansion of stone fruit cultivation in areas with suboptimal chill accumulation and the ongoing climate changes, this research aimed to evaluate effects of 17 clonal rootstocks on chill requirement for full blooming and heat accumulation for fruit development of 'BRS-Kampai' and 'BRS-Rubimel' cultivars, as well as two own-rooted scion trees. Field trials were conducted in two locations in the state of São Paulo, Brazil. Under the edaphoclimatic conditions of the study, rootstocks affected chill portions accumulated until bud break, number of days from the autumn equinox to break dormant bud stage, number of days from autumn equinox to full bloom stage, length of the fruit development period, and harvest date. Growing degree hours accumulated 30 days after full bloom stage was the single feature that showed no statistical differences among the tested rootstocks. Pearson correlations between degree days accumulated 30 days after full bloom and fruit development period were significant and more stable for 'BRS-Rubimel' than for 'BRS-Kampai', suggesting that this parameter can be used to estimate the harvest time with precision. Therefore, we concluded that rootstocks significantly influence chill accumulation required for breaking bud dormancy and reach the full bloom stage, as well as the heat accumulation for reach the harvest season.

Key words: chill portions, GDH 30, rootstock, *Prunus persica*.

INTRODUCTION

Peach [*Prunus persica* var. *vulgaris* (L.) Batsch] and nectarine (*P. persica* var. *nucipersica* Dippel.) are fruit trees from temperate zones, which need a period of low air temperature to stimulate bud development and bloom regularly in the spring season (Hawerroth et al. 2010, Delgado et al. 2024). Throughout the dormant period, trees show no vegetative growth, but they maintain metabolic activities, which allow their resistance to cold temperatures (Petri et al. 2021). Accumulation of low air temperatures during autumn and winter seasons induces uniform flowering to the peach trees. Air temperature is the major environmental factor involved in breaking dormancy of floral buds, although photoperiod (Erez 2024) and rainfall also affect this process (Hawerroth et al. 2010). Satisfying the chill requirement is important for the bud breaking and plenty peach flowering, while the heat is central for fruit growth and to predict harvest date.

Previous studies showed that air temperatures between full bloom and 30 days after this phenological stage are suitable to predict length of fruit development period (Lopez and DeJong 2007). Thus, the growing degree hours (GDH) accumulated during the period of 30 days after the full bloom stage (GDH 30) has strong correlation with harvest date in different stone fruits cultivars (Mimoun and DeJong 1999). Rootstocks, in addition to ensure adequate tree growth and resistance to abiotic and biotic stresses (Ghrab et al. 2014), potentially affect the flowering season, delaying or anticipating the bloom (Beckman et al. 1992, Durner and Goffreda 1992, Yahmed et al. 2016).

The first studies addressing chill requirements for breaking flower buds used 7.2°C as a threshold to start chill accumulation (Weinberger 1950, Petri et al. 2021). However, the advance of knowledge about peach trees physiology showed that breaking bud dormancy is related to a complex metabolic process (Hawerroth et al. 2010, Erez 2024), and the use of a single air temperature threshold is unsuitable. In view of different effects of air temperatures over chill accumulation, diverse models for rest completion of buds in temperate fruit trees were developed around the world. They consider positive, negative or null effects of air temperature (Fishman et al. 1987a, Fishman et al. 1987b, Miranda et al. 2021, Miranda 2023). Besides, the occurrence of high air temperatures during flower bud break season may negate effects of any chill previously accumulated by the tree (Richardson et al. 1974).

The dynamic model, proposed by Fishman et al. (1987a and 1987b), was selected to estimate accumulated chill, measured by chill portions (CP), for bud dormancy breaking. This model considers that the rest completion is reach in two-step process: in the first step, precursor made by low air temperature (~1.67–12.78°C) would be reversible when high air temperature occurs; in the second step, when precursor reaches a critical portion, it turns into a stable factor and does not return to the initial phase (Erez et al. 1990). This model was chosen because it performed well in extensive range of climates and its use is recommended in subtropical regions (Ghrab et al. 2014, Carbonieri and Morais 2015, Miranda et al. 2021). In addition, the dynamic model is recommended to be applied in studies addressing climate changes (Miranda 2023), has low coefficient of variation among the years, and shows high correlation with the Utah model, developed by Richardson et al. (1974; $R^2 = 0.96$), and medium correlation with 0–7.2°C model developed by Weinberger (1950; $R^2 = 0.67$) (Ghrab et al. 2014).

Since the use of rootstocks may change absorption of water and nutrients, we hypothesized that its use could affect the amount of chill required for breaking bud dormancy and flowering, and the heat essential for harvest of 'BRS Kampai' and 'BRS Rubimel' peach scions in mild winter region of São Paulo state, Brazil.

Considering the expansion of stone fruit cultivation into regions where chill accumulation is below optimal, this study aimed to evaluate the effects of 17 clonal rootstocks and own-rooted trees on the chill and heat requirements for full bud break, flowering, and harvest of two peach scion cultivars.

MATERIAL AND METHODS

Seventeen selections, species or *Prunus* cultivars (Table 1) were selected from the Embrapa Prunus Rootstock Germplasm Bank (31°40'42.00"S; 52°27'05.09"W, 54 m a.s.l.), and used as clonal rootstocks for peach based on their reaction to biotic and abiotic factors or other interesting characteristics (Neves et al. 2017, Sobierajski et al. 2021), plus two own-rooted scion trees. All rootstocks were propagated by softwood cuttings under intermittent mist system, and after acclimation and plant growth in bags under greenhouse conditions, they were budded with 'BRS Kampai' or 'BRS Rubimel' peach scion cultivars by "T inverted" budding method (Mayer et al. 2013). At the same time, own-rooted nursery trees of both peach cultivars were produced by soft cuttings. These scion peach cultivars are for fresh market, have medium tree vigor, semi-vertical tree growth behavior, and chill requirements ranging from 200 and 300 chilling hours to flowering (Raseira et al. 2014), measured according to Weinberger (1950).

Two field trials were installed in August, 2014 in the state of São Paulo, Brazil. The location of Jarinu (23°04'59"S; 46°43'27"W; 800 m. a.s.l.) present Cwa climate, according to Köppen-Geiger's classification (Alvares et al. 2013), and soil is classified as Inceptisol, according to the Brazilian Soil Classification System (Santos et al. 2018). The location of Jundiaí (23°06'52"S; 46°56'03"W; 740 m a.s.l.) also presents Cwa climate, according to Köppen-Geiger's classification (Alvares et al. 2013), but soil is classified as Ultisol, according to the Brazilian Soil Classification System (Santos et al. 2018). The trial installed in Jarinu was with trees of 'BRS Kampai' trained to a Y system spaced by 5.5 × 1.4 m, while trees of 'BRS Rubimel' were planted in Jundiaí and trained to an open vase system (5 × 4 m). Both trials were designed in randomized blocks, with six replications and one tree per plot. All cultural practices were conducted according recommendations of Moura et al. (2014).

Table 1. Identification and genetic origin of 17 selections, species, and cultivars tested as clonal rootstocks for 'BRS Kampai' and 'BRS Rubimel' peach in mild winter region of São Paulo state, Brazil.

Rootstock	Genetic origin
'Barrier'	*P. persica* × *P. davidiana*
'Cadaman'	*P. persica* × *P. davidiana*
'Capdeboscq'	*P. persica*
Clone 15	*P. mume*
'Flordaguard'	*P. persica* × *P. davidiana*
'Genovesa'	*Prunus salicina*
GxN9	*P. persica* × *Prunus dulcis*
I-67-52-4	*P. persica*
'Ishtara'	*(P. cerasifera* × *P. salicina)* × *(P. cerasifera* × *P. persica)*
México Fila-1	*P. persica*
'Nemared'	*P. persica*
'Okinawa'	*P. persica*
'Rigitano'	*P. mume*
'Santa Rosa'	*P. salicina*
'Tsukuba-1'	*P. persica*
'Tsukuba-2'	*P. persica*
'Tsukuba-3'	*P. persica*

Bud, flower, and fruit development were measured twice a week from tree pruning until physiological fruit ripening. In each tree, we marked four 1-year-old shoots, which had phenological development evaluated during consecutive seasons ('BRS Rubimel': 2016 and 2017; 'BRS Kampai': 2016 to 2018). Tree phenological stages were identified according to the E. Bellini scale (Bassi and Monet 2008), including stages from the dormant bud to the commercial ripening. Full bloom was considered when shoots had 50% of opened flowers. Fruit harvest date was considered when fruits reach the physiological stage for ripening.

Date interval was registered in Julian's days (days of the year—DOY). The number of days to break dormant bud stage (number of days E1), to reach full bloom (number of days E3), and to reach harvest date (number of days E10) were measured from the autumn equinox (in South Hemisphere: March 20th, 2016; March 21st, 2017 and 2018). The fruit development period (FDP) was measured from the interval between full bloom and harvest date, according to Marra et al. (2002). The hourly air temperature data were downloaded from an Akso datalogger (model AK172-V2) installed in both experimental orchards, with air temperature sensors placed inside a meteorological shelter.

The CP was obtained from *chill_portions* function, available in 'fruclimadapt' R-package (Miranda et al. 2021, Miranda 2023), in the R software environment (R Core Team 2023). This function requires as parameter DOY when chill accumulation is supposed to start. In this study, we standardized the autumn equinox as an indicator of beginning of chill. The GDH accumulated 30 days after full bloom stage was estimated by the Asymcur model (Anderson et al. 1986). This model put on the begins of heat accumulation when the minimum air temperature rises above a base temperature (Tb). The growth increases with air temperature up to an optimum temperature (To) and ceases when the air temperature is above a critical temperature (Tc). The estimates of GDH were obtained from *GDH_asymcur* function, available in 'fruclimadapt' package (Miranda et al. 2021, Miranda 2023). In addition, we used air temperatures Tb = 7.5°C, To = 26°C, and Tc = 38.5°C as parameters for the *GDH_asymcur* function, as specified by Marra et al. (2002), for peach fruit development.

The analyses were carried out independently for each location to account for the site-specific climatic conditions, as well as the cultivars and training systems employed. The statistical Shapiro-Wilk's test (normality), analysis of variance (ANOVA), Tukey's test and Pearson correlation were calculated at the 5% of significance level using the 'Agricolae' package (DeMendiburu 2021), and the plots drawn by the 'ggplot2' package (Wickham et al. 2019). All above cited packages were run by R software environment (R Core Team 2023).

RESULTS AND DISCUSSION

Chill portions accumulated in Jarinu (‘BRS Kampai’ trial) were 7.04 (from June 9th to August 22nd), 6.01 (from June 11th to August 22nd), and 5.95 CP (from May 21st to September 5th), respectively along the seasons from 2016 to 2018 (Fig. 1). The location of Jundiaí (‘BRS Rubimel’ trial) accumulated 6.79 (from June 5th to August 23rd) and 4.03 (from June 11th to July 18th) in 2016 and 2017, respectively (Fig. 2). These data shown that both locations present warm winter conditions, with low chill accumulated to stimulate dormant bud breaking. The knowledge of chill accumulated is essential to define species and cultivars most adapted to the local microclimate. In regions where chill requirement is not enough to break bud dormancy, growers can apply tree growth regulators to complete chill requirements (Carbonieri and Morais 2015).

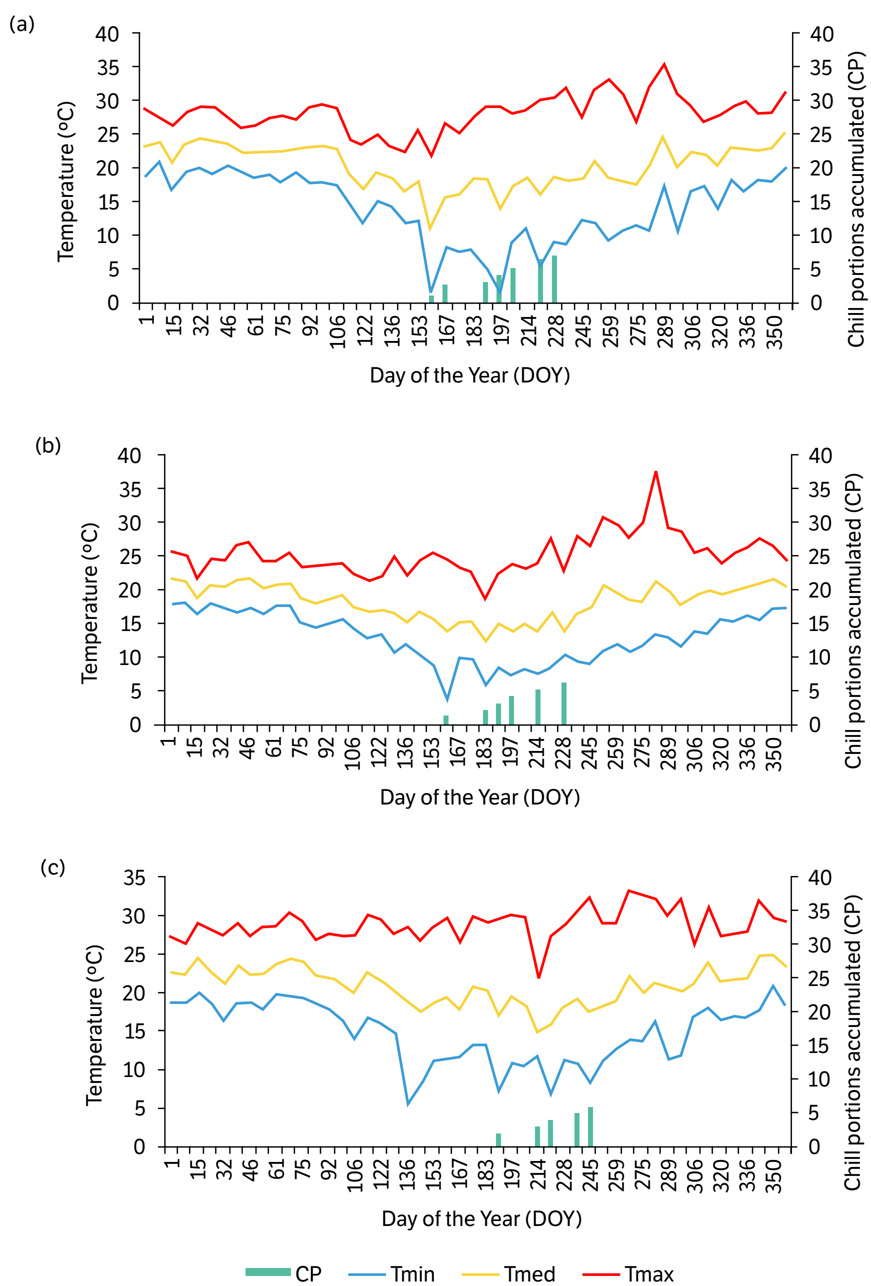


Figure 1. Maximum, medium, and minimum air temperature and chill portions accumulated. Jarinu, São Paulo state, Brazil, (a) 2016, (b) 2017, and (c) 2018.

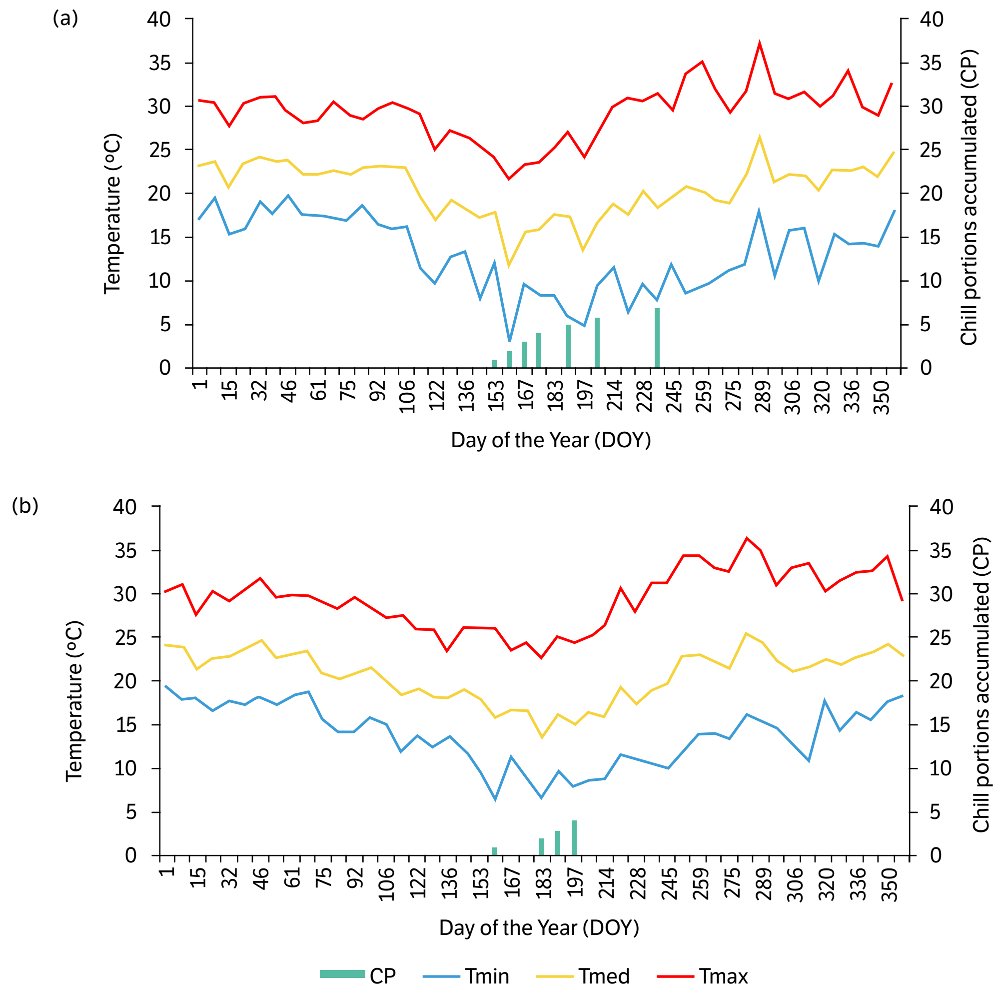


Figure 2. Maximum, medium, and minimum air temperature and chill portions accumulated. Jundiaí, São Paulo state, Brazil, (a) 2016 and (b) 2017.

The ANOVA showed statistical differences among clonal rootstocks tested to break dormant bud stage, considering the CP and number of days E1, along all seasons evaluated for 'BRS Rubimel' trial (Table 2). On the other hand, in 'BRS Kampai' trial, rootstocks presented statistical differences for CP (2017) and for the number of days from autumn equinox to the break dormancy stage (2016). This result suggests that rootstocks exert influence in breaking of bud dormancy, but with different sensitivities according to the scion cultivar. Beckman et al. (1992) indicate that differences in bloom date between rootstocks is related to differences in the onset of chill-hour accumulation or in chilling requirement of scion/rootstock combinations.

The 'BRS Kampai' trial showed a higher requirement of CP in 2017 for trees budded on 'Okinawa' (2.47 CP) and 'Tsukuba-1' rootstocks (2.31 CP) compared with other rootstocks (Table 3). The 'BRS Rubimel' trial demonstrated a high requirement of CP in 2016, for trees budded on a group of 13 rootstocks, led by the 'Tsukuba-3' (5.29 CP). In 2017, this scion also showed a higher chilling requirement when budded on a group of 17 rootstocks (ranging from 4.02 to 3.67 CP) compared with 'Tsukuba-2' rootstock (3.31 CP). According to Erez (2024), some horticultural practices may be used to compensate for low chill accumulation, such as reducing vegetative vigor by using dwarfing rootstocks, among other approaches. This is consistent with our findings, in which rootstocks with higher chilling requirements also showed greater plant height and higher nutrient uptake for most nutrient content (Sobierajski et al. 2021), resulting in enhanced vegetative growth performance.

Table 2. Analysis of variance (F test and coefficient of variation—CV%) of chill portions accumulated (CP), of number days from autumn equinox to break dormant bud stage (number of days E1), of number days from autumn equinox to the full bloom stage (number of days E3), of growing degree hours accumulated 30 days after full bloom stage (GHD 30), of fruit development period (FDP), and harvest date (number of days E10) among the own-rooted trees and 17 genotypes tested as clonal rootstocks for 'BRS Kampai' and 'BRS Rubimel' peach, respectively, in Jarinu and Jundiaí, São Paulo state, Brazil, 2016–2018.

Source of variation	BRS Kampai			BRS Rubimel	
	2016	2017	2018	2016	2017
			CP		
Rootstock	0.83^{ns}	3.99**	0.89^{ns}	1.57*	2.54*
CV%	3.67	3.93	0.46	16.04	8.47
			Number of days E1		
Rootstock	2.15*	1.53^{ns}	1.38^{ns}	2.14*	47.27**
CV%	5.22	5.34	1.53	16.16	8.97
			Number of days E3		
Rootstock	3.65**	2.28*	1.14^{ns}	2.51*	1.95*
CV%	5.10	6.69	1.85	12.99	9.60
			GDH 30		
Rootstock	1.05^{ns}	1.76^{ns}	1.42^{ns}	1.92^{ns}	1.68^{ns}
CV%	2.52	3.36	0.38	6.97	5.08
			FDP		
Rootstock	4.09**	7.40**	4.14**	2.70*	1.47*
CV%	10.14	6.91	12.31	13.15	19.50
			Number of days E10		
Rootstock	530.85**	1.40ns	3.60*	0.82^{ns}	74.39**
CV%	0.18	2.69	5.93	2.48	4.20

ns: $p \geq 0.05$; *$p < 0.05$; **$p < 0.01$.

Table 3. Chill portions accumulated (CP) from autumn equinox to break dormant bud stage among the own-rooted trees and 17 genotypes tested as clonal rootstocks for 'BRS Kampai' (2016 to 2018) and 'BRS Rubimel' (2016 and 2017) peach, respectively, in Jarinu and Jundiaí, São Paulo state, Brazil*.

Rootstock or own-rooted trees	'BRS Kampai'			'BRS Rubimel'	
	2016^{ns}	2017	2018^{ns}	2016	2017
Own-rooted trees	2.64	1.38 ab	1.92	4.17 b	3.71 ab
'Barrier'	2.64	1.34 ab	1.92	4.72 ab	3.93 a
'Cadaman'	2.64	1.97 ab	1.92	4.60 ab	3.67 ab
'Capdeboscq'	2.64	0.96 b	1.92	4.20 b	3.92 a
Clone 15	2.64	0.96 b	1.92	4.36 ab	3.88 ab
'Flordaguard'	2.64	1.09 b	1.92	4.51 ab	4.02 a
'Genovesa'	2.64	1.37 ab	1.92	5.00 ab	3.72 ab
GxN9	2.64	1.97 ab	1.92	4.04 b	3.77 ab
I-67-52-4	2.64	1.13 b	1.92	4.04 b	4.02 a
'Ishtara'	2.64	1.37 ab	1.92	4.56 ab	4.02 a
México Fila-1	2.64	0.96 b	1.92	4.39 ab	4.02 a
'Nemared'	2.64	1.16 b	1.92	4.55 ab	3.85ab
'Okinawa'	2.64	2.47 a	1.92	4.45 ab	3.81 ab
'Rigitano'	2.69	0.96 b	1.92	4.54 ab	4.02 a
'Santa Rosa'	2.64	1.67 ab	1.92	4.34 ab	3.90 ab
'Tsukuba-1'	2.70	2.31 a	1.92	4.22 b	3.73 ab
'Tsukuba-2'	2.64	1.21 b	1.92	4.63 ab	3.31 b
'Tsukuba-3'	2.64	1.10 b	1.92	5.29 a	3.93 a
Mean	2.65	1.38	1.92	4.49	3.85

*Means followed by the same letter, in the column, do not differ statistically by Tukey's test ($p \geq 0.05$); ns: $p \geq 0.05$.

'BRS Kampai' trees needed between 98.88 ('Clone 15') and 105.33 ('Nemared') days to complete the period from the autumn equinox to bud break (E1) in 2016 (Table 4). In 2017, this period ranged from 97.50 ('Capdeboscq' rootstock) to 106.50 ('Okinawa' rootstock) days, and in 2018 from 121.33 ('BRS Kampai' own-rooted trees) to 123.09 ('Tsukuba-2' rootstock) days, but no statistical differences were observed among rootstocks. For 'BRS Rubimel' trial, no significant differences were found among the 15 evaluated rootstocks in 2016, with values ranging from 97 ('I-67-52-4' rootstock) to 115 ('Tsukuba-3' rootstock) days. Only for 'GxN9' and 'Capdeboscq' rootstocks, in addition to own-rooted 'BRS Rubimel' trees, showed a shorter period to overcome bud dormancy. In 2017, 'BRS Rubimel' trees budded on 'Tsukuba-2' (197.71 days), 'Tsukuba-3' (214.91 days), and 'Tsukuba-1' (217.43 days) required significantly more days to complete the period from autumn equinox to bud break compared with the other 15 genotypes. The differences in rootstock behavior regarding bud break may be beneficial to peach growers, as they provide options for selecting rootstocks according to local climatic conditions.

Table 4. Number of days from autumn equinox to break dormant bud stage (number of days E1) among the own-rooted trees and 17 genotypes tested as clonal rootstocks for 'BRS Kampai' (2016 to 2018) and 'BRS Rubimel' (2016 and 2017) peach, respectively, in Jarinu and Jundiaí, São Paulo state, Brazil*.

Rootstock or own-rooted trees	'BRS Kampai'			'BRS Rubimel'	
	2016	2017^{ns}	2018^{ns}	2016	2017
Own-rooted trees	101.64 ab	105.07	121.33	92.17 b	136.00 b
'Barrier'	104.25 a	102.33	122.74	112.00 ab	142.45 b
'Cadaman'	100.79 ab	103.67	122.79	107.44 ab	131.65 b
'Capdeboscq'	102.80 ab	97.50	121.80	91.38 b	141.90 b
Clone 15	98.88 b	99.33	122.00	97.54 ab	136.21 b
'Flordaguard'	101.61 ab	103.15	121.73	105.67 ab	142.79 b
'Genovesa'	103.59 ab	102.25	122.00	110.42 ab	145.60 b
GxN9	101.85 ab	105.00	122.00	80.50 b	125.25 b
I-67-52-4	102.50 ab	97.83	122.63	97.00 ab	154.60 b
'Ishtara'	100.04 ab	104.17	122.00	106.38 ab	142.69 b
México Fila-1	100.79 ab	99.50	122.67	99.83 ab	138.00 b
'Nemared'	105.33 a	100.67	122.00	105.00 ab	144.17 b
'Okinawa'	100.30 ab	106.50	122.00	104.27 ab	134.79 b
'Rigitano'	102.57 ab	99.14	122.45	102.00 ab	137.73 b
'Santa Rosa'	103.50 ab	103.50	122.67	109.10 ab	145.50 b
'Tsukuba-1'	104.67 a	105.40	122.00	97.81 ab	217.43 a
'Tsukuba-2'	102.26 ab	103.60	123.09	108.33 ab	197.71 a
'Tsukuba-3'	103.50 ab	102.22	122.20	115.00 a	214.91 a
Mean	102.22	102.97	122.25	102.50	150.74

*Means followed by the same letter, in the column, do not differ statistically by Tukey's test ($p \geq 0.05$); ns: $p \geq 0.05$.

Regarding the full bloom stage, the ANOVA showed statistical differences among the rootstock effects considering the number of days from autumn equinox to the full bloom days (number of days E3), except in 2018 for 'BRS Kampai' trial (Table 2). The GDH 30, nonetheless, showed no statistical differences among the rootstock effects along with most seasons evaluated for both scion cultivars, except for 'BRS Rubimel' trial, in 2017.

The number of days E3 for 'BRS Kampai' trial, in 2016, ranged from 108.79 to 117.26, respectively, for Clone 15 and 'Barrier' rootstocks (Table 5). The largest group was formed by 13 rootstocks that needed higher number of days, ranging from 111.91 to 117.26 days. Similarly in 2017, a large group with 17 cultivars, led by own-rooted trees of 'BRS Kampai', needs more days to reach full bloom stage (between 99.10 and 108.25 days) than trees budded on 'Nemared' (98.81 days). Considering 'BRS Rubimel' trial, the largest group of rootstocks needed between 104.14 (I-67-52-4 rootstock) and 122.73 ('Tsukuba-3' rootstock) days in 2016; and between 135.25 (GxN9 rootstock) and 163.25 (I-67-52-4 rootstock) days, in 2017. Comiotto et al. (2013) evaluated the influence of six rootstocks on phenology of 'Maciel' and 'Chimarrita' peach scion, in Bento Gonçalves, RS, Brazil (29°09'44"S; 51°31'50"W; 640 m a.s.l.). The full bloom of 'Maciel' ranged from July 6th to 9th

according to the rootstock, while the 'Chimarrita' ranged from July 19th to 24th (Comiotto et al. 2013). These results emphasize that rootstocks can be a strategy to either advance or delay the full bloom season, according to the peach growers' interests.

Table 5. Number of days from autumn equinox to full bloom stage (number of days E3) among the own-rooted trees and 17 genotypes tested as clonal rootstocks for 'BRS Kampai' (2016 to 2018) and 'BRS Rubimel' (2016 and 2017) peach, respectively, in Jarinu and Jundiaí, São Paulo state, Brazil*.

Rootstock or own-rooted trees	'BRS Kampai'			'BRS Rubimel'	
	2016	2017	2018ns	2016	2017
Own-rooted trees	113.07 abcd	108.25 a	125.75	102.63 b	149.00 ab
'Barrier'	117.26 a	103.33 ab	127.14	117.50 ab	153.50 a
'Cadaman'	110.04 cd	105.54 ab	127.24	116.56 ab	144.22 ab
'Capdeboscq'	112.84 abcd	102.37 ab	126.60	100.50 b	160.80 a
Clone 15	108.79 d	105.80 ab	126.95	107.50 ab	149.92 ab
'Flordaguard'	111.91 abcd	105.45 ab	127.23	114.81 ab	149.46 ab
'Genovesa'	113.71 abcd	107.18 ab	126.48	118.30 ab	157.00 a
GxN9	115.85 abc	101.00 ab	127.29	93.50 b	135.25 ab
I-67-52-4	112.52 abcd	99.10 ab	127.92	104.14 ab	163.25 a
'Ishtara'	111.08 bcd	101.20 ab	126.91	120.00 ab	154.93 a
México Fila-1	113.50 abcd	107.00 ab	127.53	106.10 ab	147.50 ab
'Nemared'	117.13 ab	98.81 b	126.93	112.92 ab	155.67 a
'Okinawa'	110.94 bcd	101.83 ab	127.44	110.38 ab	144.31 ab
'Rigitano'	115.12 abc	105.46 ab	127.14	116.29 ab	148.50 ab
'Santa Rosa'	116.23 ab	104.52 ab	127.85	116.50 ab	156.44 a
'Tsukuba-1'	113.39 abcd	102.29 ab	126.62	105.50 ab	147.31 ab
'Tsukuba-2'	111.57 bcd	101.28 ab	127.47	111.60 ab	127.67 b
'Tsukuba-3'	113.00 abcd	105.00 ab	127.00	122.73 a	147.46 ab
Mean	113.17	103.84	127.06	111.21	149.73

*Means followed by the same letter, in the column, do not differ statistically by Tukey's test ($p \geq 0.05$); ns: $p \geq 0.05$.

A trial conducted by Jimenes (2017), which evaluated 'Sunraycer' nectarine scion on 13 clonal rootstocks and own-rooted scion trees in Piracicaba, SP, Brazil (22°42'30"S, 47°38'30"W; 546 m a.s.l.), found no differences in full bloom dates (July 1st; DOY = 182) among different treatments. Ghrab et al. (2014) evaluated peach scions 'Early May Crest' and 'Royal Glory' grafted on 'GF677' and 'Cadaman' rootstocks Mornag region (36°41' N, 10°15' E) in northern Tunisia, and reported differences in number of days to full bloom depending on the rootstock.

According to the authors, flowering period ranged from 14 to 17 days for trees with different scion-rootstock combinations in years with typical winter conditions. In years with low chill accumulation, this flowering duration ranges only from three to five days. These relatively small differences, which provide limited practical benefits, are expected to become increasingly common under projected climate change scenarios. These differences in full bloom stage suggest variations in chilling requirements based on the scion/rootstock combination (Beckman et al. 1992), which demands research at microregional level, such as that carried out in this paper. The mean GDH 30 values estimated for 'BRS Kampai' were 6,499.16, 5,905.53, and 6,425.82 in 2016, 2017, and 2018, respectively; and for 'BRS Rubimel', 6,677.65 in 2016 and 7,474.94 in 2017. No statistical differences were observed among the 17 rootstocks and the own-rooted trees (Tables 2 and 6). In other words, although rootstocks influenced number of days E3, they did not significantly affect GHD 30 heat requirement.

The ANOVA results showed significant differences in effects of 17 rootstocks and the own-rooted scion trees on the FDP across all evaluated seasons for both scion cultivars (Table 2). However, no statistical differences were observed in the number of days E10 in 2017 ('BRS Kampai' trial) and in 2016 ('BRS Rubimel' trial). Tukey's test for FDP revealed a wide variation in the effects of rootstocks (Table 7). For the scion 'BRS Kampai', 'Okinawa' was the most stable rootstock, consistently remaining in group of the less precocious genotypes across all seasons, whereas for 'BRS Rubimel', the rootstock 'Genovesa' required the greatest number of days for fruit development. In contrast, none of the most precocious rootstocks showed stable behavior.

Table 6. Growing degree hours accumulated 30 days (GDH 30) after the full bloom stage among 17 rootstocks and the scions 'BRS Kampai' (2016 to 2018) and 'BRS Rubimel' (2016 and 2017) own rooted, respectively in Jarinu and Jundiaí, São Paulo state, Brazil*.

Rootstock cultivar	'BRS Kampai'			'BRS Rubimel'	
	2016[ns]	2017[ns]	2018[ns]	2016[ns]	2017[ns]
Scion own rooted	6,483.65	6,020.48	6,428.93	6,417.86	7,534.76
'Barrier'	6,508.63	5,898.05	6,422.54	6,793.13	7,433.78
'Cadaman'	6,464.02	5,988.33	6,434.67	6,823.15	7,325.84
'Capdeboscq'	6,511.63	5,872.74	6,424.42	6,465.27	7,541.66
'Clone 15'	6,541.80	5,929.76	6,423.82	6,558.84	7,358.45
'Flordaguard'	6,488.02	5,917.45	6,422.80	6,743.51	7,429.03
'Genovesa'	6,589.85	5,701.30	6,421.29	6,322.75	7,114.25
'GxN9'	6,438.26	6,004.76	6,425.63	6,935.48	7,731.13
'I-67-52-4'	6,470.54	5,766.07	6,440.61	6,471.91	7,680.63
'Ishtara'	6,478.19	5,822.74	6,423.42	6,886.11	7,646.36
'México Fila-1'	6,507.73	5,968.24	6,420.19	6,521.21	7,401.08
'Nemared'	6,479.53	5,782.55	6,424.52	6,835.44	7,487.17
'Okinawa'	6,511.86	5,860.63	6,422.61	6,586.01	7,343.26
'Rigitano'	6,517.68	5,955.46	6,421.82	6,859.72	7,367.98
'Santa Rosa'	6,548.55	5,931.89	6,417.10	6,815.73	7,790.80
'Tsukuba-1'	6,509.07	5,884.36	6,425.04	6,471.23	7,367.09
'Tsukuba-2'	6,491.61	5,864.45	6,421.08	6,683.34	6,992.04
'Tsukuba-3'	6,461.20	5,912.25	6,442.16	7,015.74	7,387.70
Mean	6,499.16	5,905.53	6,425.82	6,677.65	7,449.94

*Means followed by the same letter, in the column, do not differ statistically by Tukey's test ($p \geq 0.05$); ns: $p \geq 0.05$.

Table 7. Fruit development period (FDP) among trees budded on 17 rootstocks and 'BRS Kampai' (2016 to 2018) and 'BRS Rubimel' (2016 and 2017) own rooted trees, respectively in Jarinu and Jundiaí, São Paulo state, Brazil*.

Rootstock cultivar	'BRS Kampai'			'BRS Rubimel'	
	2016	2017	2018	2016	2017
Scion own rooted	112.93 ab	97.08 c	74.50 c	114.05 ab	86.85 ab
'Barrier'	107.84 bc	105.29 abc	92.77 a	106.40 ab	82.78 ab
'Cadaman'	115.26 ab	103.21 abc	87.75 ab	102.44 ab	89.78 ab
'Capdeboscq'	112.53 ab	106.39 abc	85.93 ab	118.50 ab	70.95 b
'Clone 15'	116.44 ab	106.20 abc	80.85 bc	111.50 ab	84.45 ab
'Flordaguard'	113.45 ab	86.55 c	89.63 ab	100.03 ab	86.31 ab
'Genovesa'	109.15 abc	107.76 abc	70.46 c	125.50 a	110.50 a
'GxN9'	119.24 a	104.82 abc	88.02 ab	100.70 ab	79.52 ab
'I-67-52-4'	112.67 ab	112.90 a	84.82 abc	114.86 ab	75.50 ab
'Ishtara'	114.56 ab	106.69 abc	80.98 bc	99.00 ab	81.04 ab
'México Fila-1'	111.71 ab	105.00 abc	83.52 abc	105.62 ab	79.69 ab
'Nemared'	109.18 abc	109.95 ab	84.13 abc	106.08 ab	81.36 ab
'Okinawa'	114.53 ab	110.17 ab	89.60 ab	112.44 ab	87.68 ab
'Rigitano'	96.88 c	106.54 abc	85.69 ab	106.71 ab	81.50 ab
'Santa Rosa'	109.20 ab	107.48 abc	85.15 abc	102.50 ab	84.19 ab
'Tsukuba-1'	112.10 ab	109.71 ab	84.22 abc	115.83 ab	87.35 ab
'Tsukuba-2'	113.75 ab	102.72 bc	86.05 ab	104.60 ab	99.83 ab
'Tsukuba-3'	112.41 ab	103.67 abc	91.67 ab	95.48 b	85.16 ab
Mean	111.90	105.38	85.06	107.35	84.94

*Means followed by the same letter, in the column, do not differ statistically by Tukey's test ($p \geq 0.05$); ns: $p \geq 0.05$.

For the scion 'BRS Kampai', the number of days E10 ranged from 212 to 226.14 DOY in 2016, with 'Rigitano' rootstock representing the most precocious and 'Nemared' rootstock the latest harvest (Table 8). In 2017, harvest dates ranged from 192 to 212 DOY among rootstocks, including 'Rigitano', 'GxN9', 'I-67-52-4', 'México Fila-1', 'Okinawa', 'Santa Rosa', and 'Tsukuba-1', with no significant differences observed. In 2018, harvest dates ranged from 197.75 to 221.54 DOY, representing the most and least precocious rootstocks, respectively. In the 'BRS Rubimel' trial, harvest dates in 2016 ranged from 213.40 to 222.11 DOY, with 'México Fila-1' as the most precocious and 'Okinawa' as the latest, with no statistical differences. In 2017, rootstocks budded with 'BRS Rubimel' formed two groups: the most precocious ranged from 250.50 to 312 DOY, and the latest from 312 to 327.33 DOY.

Table 8. Harvest date (number of days E10) among trees budded on 17 rootstocks and 'BRS Kampai' (2016 to 2018) and 'BRS Rubimel' (2016 and 2017) own rooted trees, respectively in Jarinu and Jundiaí, São Paulo state, Brazil*.

Rootstock cultivar	'BRS Kampai'			'BRS Rubimel'	
	2016	2017^{ns}	2018	2016^{ns}	2017
Scion own rooted	226.00 a	205.33	200.25 c	217.00	242.00 a
'Barrier'	225.06 b	208.67	221.54 a	221.80	237.30 a
'Cadaman'	225.21 b	208.47	213.86 ab	219.00	238.36 a
'Capdeboscq'	225.25 b	208.47	212.53 abc	219.00	240.33 a
'Clone 15'	225.17 b	212.00	206.70 bc	219.00	239.89 a
'Flordaguard'	225.27 b	192.00	216.86 ab	215.50	240.38 a
'Genovesa'	225.00 b	208.47	197.75 c	219.00	245.75 a
'GxN9'	225.17 b	212.00	214.52 ab	219.00	242.20 a
'I-67-52-4'	225.12 b	212.00	212.74 abc	219.00	240.00 a
'Ishtara'	225.57 ab	208.00	208.61 bc	219.00	250.50 a
'México Fila-1'	225.13 b	212.00	211.95 abc	213.40	312.40 b
'Nemared'	226.14 a	208.47	209.43 abc	219.00	323.89 b
'Okinawa'	225.31 b	212.00	216.76 ab	222.11	316.29 b
'Rigitano'	212.00 c	212.00	212.43 abc	221.80	320.00 b
'Santa Rosa'	225.33 b	212.00	213.39 ab	219.00	327.33 b
'Tsukuba-1'	225.36 b	212.00	212.64 abc	219.00	320.29 b
'Tsukuba-2'	225.25 b	204.00	212.91 abc	217.25	312.00 b
'Tsukuba-3'	225.30 b	208.67	216.22 ab	220.75	320.00 b
Mean	224.67	208.47	212.14	219.00	272.85

*Means followed by the same letter, in the column, do not differ statistically by Tukey's test ($p \geq 0.05$); ns: $p \geq 0.05$.

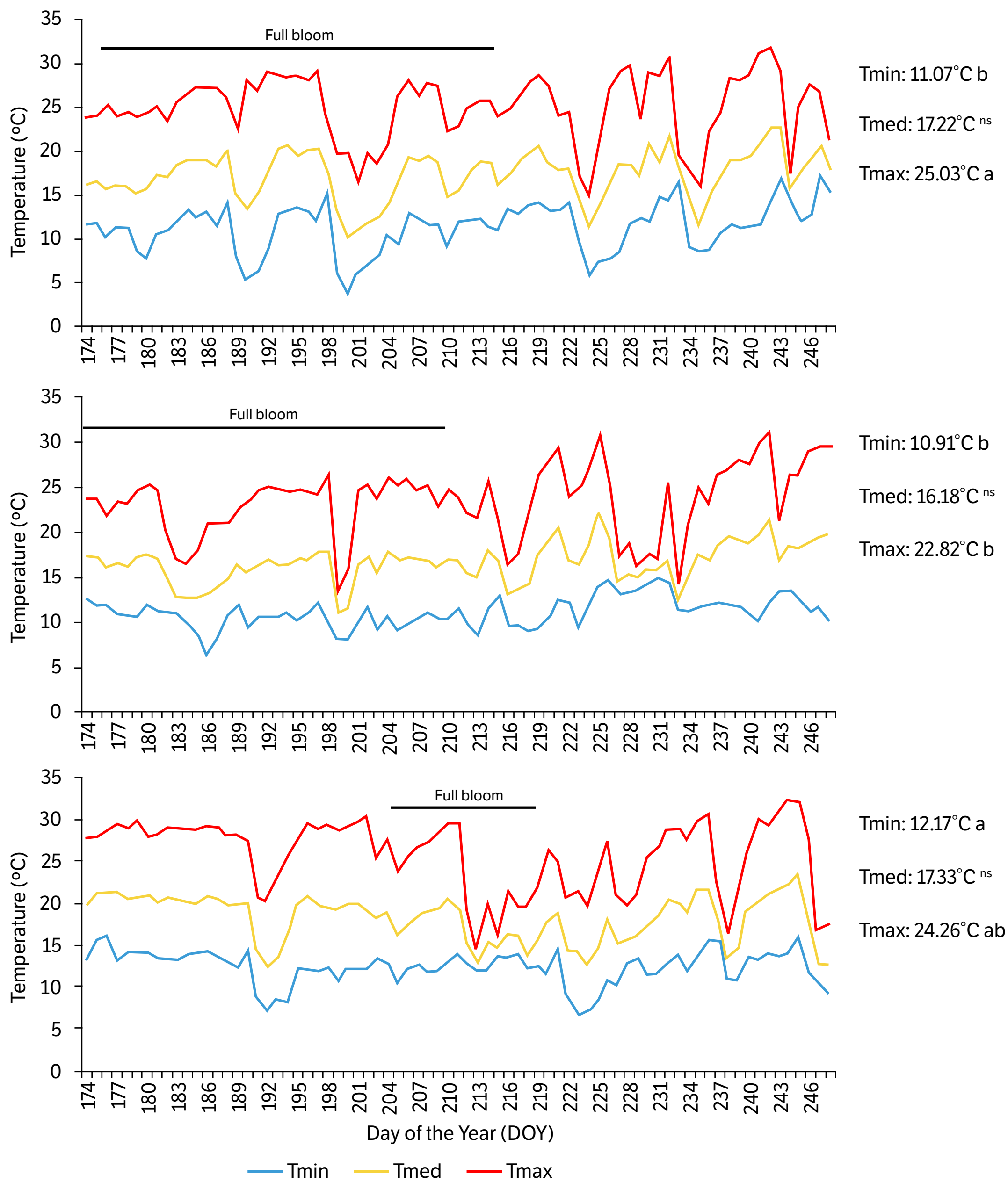
Figures 3 and 4 depict the minimum, mean, and maximum daily temperatures, including results of the Tukey's test among years, over the period from full bloom to 30 days after this phenological stage, for the locations of Jarinu (cv. 'BRS Kampai') and Jundiaí (cv. 'BRS Rubimel'), respectively. These figures also indicate the range of the full bloom stage. It can be observed that, regardless of air temperature range after full bloom, this did not bias the behavior of rootstocks or the estimation of GDH 30. Only the FDP showed significant differences among rootstocks in all seasons for both scion cultivars.

The Pearson correlation between GDH 30 and FDP showed moderate to high correlations for 'BRS Kampai' and 'BRS Rubimel' scions, except in 2018 for 'BRS Kampai', which showed a low and non-significant correlation (Table 9). Even in years with significant correlations, the strength of the correlation varied. The highest correlation for 'BRS Kampai' occurred in 2017, when minimum and maximum air temperatures were significantly lower than in other years (Fig. 3). This suggests that the average minimum air temperature may have a greater influence on GDH 30 calculation and, consequently, on the correlation with FDP. Conversely, in 2018, no linear correlation was observed between GDH 30 and FDP, and the average minimum and maximum air temperatures were higher than in the other evaluated years. A similar pattern was observed for 'BRS Rubimel': 2016, the year with the highest correlation, also had the lowest average air temperatures (Fig. 4). These results suggest that the instability of the correlations may be due to variable climatic conditions, which are common in tropical regions.

Table 9. Pearson correlation (ρ) between growing degree hours accumulated 30 days after the full bloom stage and the fruit development period among trees budded on 17 rootstocks and 'BRS Kampai' and 'BRS Rubimel' own rooted trees, respectively in Jarinu and Jundiaí, São Paulo state, Brazil, 2016–2018.

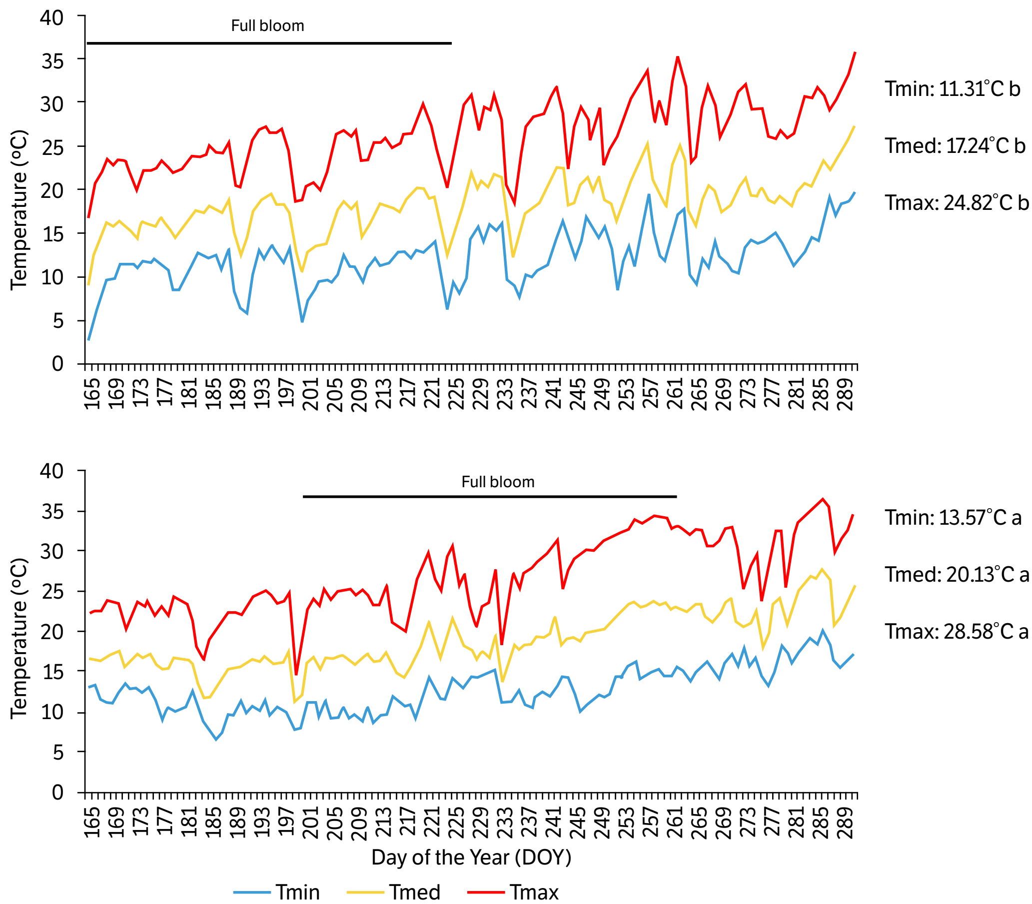
Correlation	2016	2017	2018
		'BRS Kampai'	
ρ	-0.2415*	-0.7864*	-0.0325^{ns}
		'BRS Rubimel'	
ρ	-0.9099*	-0.7738*	N.E.

ns: $p \geq 0.05$; *$p < 0.05$. N.E.: not evaluated.



ns: $p \geq 0.05$; *$p < 0.05$; **$p < 0.01$.

Figure 3. Minimum, mean, and maximum air temperatures (°C) during full bloom stage and 30 days after this phenological stage in Jarinu, São Paulo state, Brazil, from 2016 to 2018. F test, coefficient of variation and Tukey's test (air temperatures between full bloom and 30 days after this phenological stage) among years: Tmin = 5.11*, 20.11%; Tmed = 0.02ns, 15.71%; Tmax = 1.77*, 17.54%.



ns: $p \geq 0.05$; $^{*}p < 0.05$; $^{**}p < 0.01$.

Figure 4. Minimum, mean, and maximum air temperatures (°C) during full bloom stage and 30 days after this phenological stage in Jundiaí, São Paulo state, Brazil, from 2016 to 2017. F test, coefficient of variation and Tukey's test (air temperatures between full bloom and 30 days after this phenological stage) between years: Tmin = 31.12**, 21.87%; Tmed = 41.89**, 16.08%; Tmax = 43.58**, 14.33%.

CONCLUSION

Under the edaphoclimatic conditions of this study, different Prunus spp. genotypes used as clonal rootstocks significantly influenced bud dormancy release, flowering phenology, and harvest timing of 'BRS Kampai' and 'BRS Rubimel' peach scions. These effects provide relevant information for orchard establishment in areas with limited chilling accumulation. The results could possibly be applied to frost risk management during flowering and to harvest scheduling by either advancing or delaying the flowering season.

Correlations between growing degree hours accumulated during the 30 days after full bloom and length of fruit development period, evaluated across 17 rootstocks and two own-rooted peach scions, ranged from weak and non-significant to strong and statistically significant, depending on the year. This variability indicates that the reliability of predicting harvest date based solely on post-bloom heat accumulation may be negatively affected by the genotype and seasonal climatic conditions.

CONFLICT OF INTEREST

Nothing to declare.

AUTHORS' CONTRIBUTION

Conceptualization: Mayer, N. A. and Sobierajski, G. R.; **Investigation:** Sobierajski, G. R., Blain, G. C. and Mayer, N. A.; **Methodology:** Sobierajski, G. R., Blain, G. C. and Mayer, N. A.; **Formal analysis:** Sobierajski, G. R. and Blain, G. C.; **Software:** Sobierajski, G. R. and Blain, G. C.; **Writing – original draft:** Sobierajski, G. R. and Blain, G. C.; **Writing – review & editing:** Sobierajski, G. R., Blain, G. C. and Mayer, N. A.; **Supervision:** Sobierajski, G. R.; **Final approval:** Sobierajski, G. R.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

FUNDING

Conselho Nacional de Desenvolvimento Científico e Tecnológico
Grant No.: 304609/2022-6

DECLARATION OF USE OF ARTIFICIAL INTELLIGENCE TOOLS

The authors declare that no artificial intelligence tools were used in the preparation, writing, data analysis, or review of this manuscript.

ACKNOWLEDGMENTS

To the Irmãos Parise Hortifruti for supporting the field trial in Jarinu.

REFERENCES

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Moraes Gonçalves, J. L. and Sparovek, G. (2013). Köppen's climate classification map for Brazil. Meteorologische Zeitschrift, 22, 711-728. https://doi.org/10.1127/0941-2948/2013/0507

Anderson, J. L., Richardson, E. A. and Kesner, C. D. (1986). Validation of chill unit and flower bud phenology models for "Montmorency" sour cherry. Acta Horticulturae, 184, 71-78. https://doi.org/10.17660/ActaHortic.1986.184.7

Bassi, D. and Monet, T. (2008). Botany and taxomony. In D. R. Layne and D. Bassi (Eds.). The peach: botany, production and uses (p. 1-36). Oxfordshire: CABI.

Beckman, T. G., Okie, W. R. and Meyers, S. C. (1992). Rootstock affect bloom date and fruit maturation of 'Redhaven' peach. Journal of the American Society for Horticultural Science, 117, 377-379. https://doi.org/10.21273/JASHS.117.3.377

Carbonieri, J. and Morais, H. (2015). Horas e unidades de frio em pomares de maçã com diferentes microclimas. Revista Brasileira de Fruticultura, 37, 1-12. https://doi.org/10.1590/0100-2945-005/14

Comiotto, A., Fachinello, J. C., Hoffmann, A., Galarça, S. P., Machado, N. P., Prezotto, M. E. and Hass, L. B. (2013). Desenvolvimento, produção e qualidade dos frutos de pessegueiros enxertados sobre diferentes porta-enxertos. Semina: Ciencias Agrárias, 34, 3553-3562. https://doi.org/10.5433/1679-0359.2013v34n6Supl1p3553

Delgado, A., Egea, J. A., Fernandez, E., Campoy, J. A., Egea, J., Dicenta, F. and Ruiz, D. (2024). Discrepancies in methodologies to determine chill requirements in temperate fruit trees constrain guidelines for future plantings in a global warming context. Agricultural and Forest Meteorology, 349, 109970. https://doi.org/10.1016/j.agrformet.2024.109970

DeMendiburu, F. (2021). Package agricolae. Available at: https://cran.r-project.org/web/packages/agricolae/agricolae.pdf. Accessed on: Feb. 16, 2022.

Durner, E. F. and Goffreda, J. C. (1992). Rootstock-induced differences in flower bud phenology in peach. Journal of the American Society for Horticultural Science, 117, 690-697. https://doi.org/10.21273/JASHS.117.5.690

Erez, A. (2024). Overcoming dormancy in prunus species under conditions of insufficient winter chilling in Israel. Plants, 13, 764. https://doi.org/10.3390/plants13060764

Erez, A., Fishman, S., Linsley-Noakes, G. C. and Allan, P. (1990). The dynamic model for rest completion in peach buds. Acta Horticulturae, 165-174. https://doi.org/10.17660/ActaHortic.1990.276.18

Fishman, S., Erez, A. and Couvillon, G. A. (1987a). The temperature dependence of dormancy breaking in plants: Computer simulation of processes studied under controlled temperatures. Journal of Theoretical Biology, 126, 309-321. https://doi.org/10.1016/S0022-5193(87)80237-0

Fishman, S., Erez, A. and Couvillon, G. A. (1987b). The temperature dependence of dormancy breaking in plants: Mathematical analysis of a two-step model involving a cooperative transition. Journal of Theoretical Biology, 124, 473-483. https://doi.org/10.1016/S0022-5193(87)80221-7

Ghrab, M., Mimoun, M. B., Masmoudi, M. M. and Mechlia, N. B. (2014). Chilling trends in a warm production area and their impact on flowering and fruiting of peach trees. Scientia Horticulturae, 178, 87-94. https://doi.org/10.1016/j.scienta.2014.08.008

Hawerroth, F. J., Herter, F. G., Petri, J. L., Leite, G. B. and Pereira, J. F. M. (2010). Dormência em frutíferas de clima temperado. Pelotas: Embrapa Clima Temperado.

Jimenes, I. M. (2017). Desempenho agronômico e nutricional da nectarineira Sunraycer autoenraizada e enxertada sobre porta-enxertos clonais. Piracicaba: ESALQ/USP.

Lopez, G. and DeJong, T. M. (2007). Spring temperatures have a major effect on early stages of peach fruit growth. Journal of Horticultural Science & Biotechnology, 82, 507-512. https://doi.org/10.1080/14620316.2007.11512266

Marra, F. P., Inglese, P., DeJong, T. M. and Johnson, R. S. (2002). Thermal time requirement and harvest time forecast for peach cultivars with different fruit development periods. Acta Horticulturae, 592, 523-529. https://doi.org/10.17660/ActaHortic.2002.592.70

Mayer, N. A., Ueno, B., Fischer, C. and Migliorini, L. C. (2013). Propagação vegetativa de frutíferas de caroço por estacas herbáceas em escala comercial. Pelotas: Embrapa.

Mimoun, M. B. and DeJong, T. M. (1999). Using the relation between growing degree hours and harvest date to estimate run-times for peach: a tree growth and yield simulation model. Acta Horticulturae, 499, 107-114. https://doi.org/10.17660/ActaHortic.1999.499.10

Miranda, C. (2023). Package "fruclimadapt". Available at: https://cran.r-project.org/web/packages/fruclimadapt/fruclimadapt.pdf. Accessed on: July 31, 2023.

Miranda, C., Urrestarazu, J. and Santesteban, L. G. (2021). fruclimadapt: An R package for climate adaptation assessment of temperate fruit species. Computers and Electronics in Agriculture, 180, 105879. https://doi.org/10.1016/j.compag.2020.105879

Moura, M. F., Sobierajski, G. R. and Tecchio, M. A. (2014). Pêssego. In A. T. E. Aguiar, C. Gonçalves, M. E. A. G. Z. Paterniani, M. L. Tucci and C. E. F. Castro (Eds.). Instruções agrícolas para as principais culturas econômicas (7. ed., p. 342-347). Campinas: Instituto Agronômico. Boletim 200.

Neves, T. R., Mayer, N. A. and Ueno, B. (2017). Graft incompatibility in prunus spp. preceded by spad index reduction. Semina: Ciências Agrárias, 38, 635-648. https://doi.org/10.5433/1679-0359.2017v38n2p635

Petri, J. L., Sezerino, A. A., Hawerroth, F. J., Palladini, L. A., Leite, G. B. and Martin, M. S. (2021). Dormência e indução à brotação de árvores frutíferas de clima temperado. Florianópolis: EPAGRI.

R Core Team (2023). R: a language and environment for statistical computing - v. 4.3.1. Available at: http://www.r-project.org. Accessed on: June 15, 2023.

Raseira, M. C. B., Nakasu, B. H. and Barbosa W. (2014). Cultivares: descrição e recomendação. In M. C. B. Raseira, J. F. M. Pereira and F. L. C. Carvalho (Eds.). Pessegueiro (p. 73-141). Brasília: Embrapa.

Richardson, E. A., Seeley, S. D. and Walker, D. R. (1974). A model for estimating the completion of rest for Redhaven and Elberta peach trees. Hortscience, 9, 331-332. https://doi.org/10.21273/HORTSCI.9.4.331

Santos, H. G., Jacomine, P. K. T., Anjos, L. H. C., Oliveira, V. Á., Lumbreras, J. F., Coelho, M. R., Almeida, J. A., Araújo Filho, J. C., Oliveira, J. B. and Cunha, T. J. F. (2018). Sistema brasileiro de classificação de solos. 5. ed. Brasilia: Embrapa.

Sobierajski, G. R., Blain, G. C., Teixeira, L. A. J. and Mayer, N. A. (2021). Vegetative growth and foliar nutrient contents of peach on different clonal rootstocks. Pesquisa Agropecuária Brasileira, 56, e02043. https://doi.org/10.1590/s1678-3921.pab2021.v56.02043

Weinberger, J. H. (1950). Chilling requirements of peach varieties. Proceedings of the American Society for Horticultural Science, 56, 122-128.

Wickham, H., Chang, W., Henry, L., Pedersen, T. L., Takahashi, K., Wilke, K. and Woo, K. (2019). Package ggplot2. Available at: https://cran.r-project.org/web/packages/ggplot2/ggplot2.pdf. Accessed on: May 5, 2019.

Yahmed, J. B., Ghrab, M., Moreno, M. Á., Pinochet, J. and Mimoun, M. B. (2016). Performance of 'Subirana' flat peach cultivar budded on different Prunus rootstocks in a warm production area in North Africa. Scientia Horticulturae, 206, 24-32. https://doi.org/10.1016/j.scienta.2016.04.031