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REPRODUCTIVE PHENOLOGY OF PEACH PALMS (*Bactris gasipaes* KUNTH, ARECACEAE) GROWING IN THE STATE OF SÃO PAULO [1]

FENOLOGIA REPRODUTIVA DE PUPUNHEIRAS (*Bactris gasipaes* KUNTH, ARECACEAE) CULTIVADAS NO ESTADO DE SÃO PAULO

Valéria Aparecida MODOLO[2,4]; Antonio Lúcio Melo MARTINS[3]; Angélica PRELA-PANTANO[2]; Norma de Magalhães ERISMANN[2]; Iago Felipe Nogueira PIRAMO[2]; João Batista Lima SOUSA[2]; Camila SILVERIO[2]

ABSTRACT - Peach palm (*Bactris gasipaes* Kunth) was commercially introduced in São Paulo in the 1980s, as an alternative for heart-of-palm production, being currently the main species cultivated for this purpose. Phenological studies on flowering/fruiting, in addition to contributing to the breeding program, can provide subsidies for seed production technology. The objective of this research was to evaluate the reproductive phenology of peach palm, to relate the observed patterns with climatic elements and estimate its stages when cultivated in three locations in the State of São Paulo. The experiments were carried out in the IAC Peach Palm Collection, planted in September/1992, in Pariquera-Açu; Pindorama and Mococa. We selected 173, 282 and 150 plants for phenology evaluation and 30, 32 and 33 plants to estimate the stages, between July/June, in different years for each area, between 2013 and 2019. Data were analyzed by the activity index and by the Spearman correlation (rs) between the percentage of peach palms in each phenophase in the month and the climatic variables in the same month, from one and two months earlier. The flowering time depends on the location where the palm is cultivated, influenced by the average temperature and evapotranspiration in Pariquera-Açu and by precipitation in Mococa. The prevailing climatic elements in fruiting in the three locations are evapotranspiration and average temperature in the month preceding the phenological event and in Mococa it is also influenced by precipitation. The time for peach palms flowering varies from 41 to 50 days and the fruiting lasts 116 days in Pindorama.

Keywords: *Bactris gasipaes*; Flowering, Fruiting; Heart-of-palm; Peach Palm.

RESUMO - A pupunheira (*Bactris gasipaes* Kunth) foi introduzida comercialmente em São Paulo na década de 1980, como alternativa para produção de palmito, sendo atualmente a principal espécie cultivada para esse fim. Estudos fenológicos sobre floração/frutificação, além de contribuir para o programa de melhoramento podem fornecer subsídios para tecnologia de produção de sementes. O objetivo desta pesquisa foi avaliar a fenologia reprodutiva de pupunheira, relacionar os padrões observados com elementos climáticos e estimar suas etapas quando cultivada em três locais do Estado de São Paulo. Os experimentos foram realizados na Coleção de Pupunheiras do IAC, plantadas em setembro/1992, em Pariquera-Açu, Pindorama e Mococa. Foram selecionadas 173, 282 e 150 plantas para avaliação da fenologia e 30, 32 e 33 plantas para estimar as etapas, entre julho/junho em anos distintos para cada área, entre 2013 e 2019. Os dados foram analisados pelo índice de atividade e pela correlação de Spearman (rs) entre a porcentagem de pupunheiras em cada fenofase no mês e as variáveis climáticas no mesmo mês, de um e dois meses anteriores. A época de floração de pupunheira depende do local onde a palmeira é cultivada, influenciada pela temperatura média e evapotranspiração em Pariquera-Açu e pela precipitação em Mococa. Os elementos climáticos preponderantes na frutificação nos três locais são evapotranspiração e temperatura média no mês anterior ao evento fenológico e em Mococa também é influenciada pela precipitação. O tempo para a floração de pupunheiras varia de 41 a 50 dias e a frutificação dura 116 dias em Pindorama.

Palavras-chave: *Bactris gasipaes*; Floração, Frutificação; Palmito; Pupunha.

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[2] Instituto Agronômico (IAC/APTA), Av. Barão de Itapura, 1.481, 13.020-902, Campinas, SP, Brazil.
[3] APTA Centro Norte, Rodovia Washington Luiz, km 372, 15830-000, Pindorama, SP, Brazil.
[4] Corresponding author: Valéria A. Modolo - valeria.modolo@sp.gov.br.

1 INTRODUCTION

Peach palm (*Bactris gasipaes* Kunth) occurs in the humid American tropics from northern Honduras, along the Atlantic coast in Central and South America to São Luís do Maranhão in Brazil, and along the Pacific coast, from southern Costa Rica to northern Peru (Almeyda and Martin, 1980). It is widely distributed in the Amazon Basin, in an area comprising Bolivia, Brazil, Colombia, Peru and Venezuela. It is a perennial, cespitose palm (it has tillers forming a clump), whose stem (stipe) can reach up to 20 m in height and 15 to 25 cm in diameter. It can be found in two basic types: with and without spines in the stem and/or in the petiole and rachis of the leaves (Mora-Urpí et al., 1997). Its fruits are rich in proteins, carbohydrates and various mineral nutrients, such as calcium, iron and phosphorus, in addition to having a high content of vitamin A and its consumption, after cooking in water and salt, is definitely integrated with the eating habits of the area that covers the States of the region of origin (Clement, 2000). In the State of São Paulo, it was introduced as an alternative for the production of heart-of-palm, since the main species for this purpose, the juçara palm (*Euterpe edulis* Mart.), was being decimated by indiscriminate extraction. Currently it is the main species cultivated for heart-of-palm production, mainly due to its cultivation characteristics, such as precocity and tillering (Modolo et al., 2018).

Research in Brazil with the peach palm for the production of heart-of- palm began in the early 1970s at the Instituto Agronômico de Campinas - IAC (Germek, 1978) and at the end of the same decade at the Instituto Nacional de Pesquisas da Amazônia (Moreira Gomes and Arkcoll, 1988). In that decade, the IAC Peach Palm Collection began to be formed in the State of São Paulo, with the purpose of studies in the areas of phytotechnics and breeding, with the introduction of peach palm accessions from the Brazilian Amazon, Costa Rica and Peru (Bovi et al., 1987). Subsequently, in the 1990s, there were introductions of seeds of spineless peach palm from the region of Yurimaguas, Peru, planted in different edaphoclimatic regions of the State (coast and plateau of São Paulo) and, consequently, have different climatic characteristics (Modolo et al., 2019). Over the years, it was observed that there were differences in the flowering/fruiting times of the palms depending on the region and the state, which could be better studied for the extension of the peach palm breeding program.

Climatic variations occur periodically throughout the year and every day, especially in response to the balance of solar radiation. On the other hand, aperiodic oscillations can occur throughout the year, changing the phenological pattern of the plants, from one year to another (Bergamaschi, 2007). Both Mora-Urpí and Solís (1980) and Ferreira (2005) had already mentioned that in native peach palms the season of fruit production could vary from year to year according to the rainy and dry periods. However, there are few studies that describe the phenology of peach palm grown in tropical and subtropical conditions.

Knowledge about phenological patterns of any species is essential to support stages of genetic improvement programs, management and domestication of the species, plants and environment relations (Jardim and Kageyama, 1994; Oliveira et al, 2003). From an agronomic point of view, phenological studies of flowering/fruiting of peach palm in different regions of São Paulo State, in addition to contributing to the species breeding program, will serve as a subsidy to establish seed production technology in the State.

The objective of this research was to evaluate the reproductive phenology of peach palm, to relate the observed patterns with climatic elements and estimate its stages when cultivated in three locations in the State of São Paulo.

2 MATERIAL AND METHODS

2.1 Study areas and characterization of peach palm collections

The experiment was carried out on cultivated individuals from the IAC Peach Palm Collection, which is composed of 332 half-sibling progenies, obtained from seeds from the collection of fruits in parent plants located in Yurimáguas, Peru, in the regions of the hydrographic basins of Huallaga, Cuiparillo, Paranapura and Shanusi. The seeds were collected in 1991 and the seedlings of the progenies were planted in two distinct regions of São Paulo State (coast and plateau of São Paulo), in September 1992.

Area I: Located in the Polo APTA Vale do Ribeira located in the municipality of Pariquera-Açu (24°36'31"S and 47°53'48"O, at 25 m of altitude above sea level), SP. The region is characterized as Cfa (Köppen) climate, Humid Subtropical Climate, with hot/humid characteristics with temperatures below 18°C in the coldest month and above 22°C in the hottest month and average precipitation of 1,678 mm, without defined seasons (Ortolani et al., 1995). Collection composed of 332 progenies, one plant/progeny, cultivated without tiller management and without irrigation, planted at 5 x 5 m spacing, totaling an area of 0.83 ha.

Area II: Located in the Polo APTA Centro Norte, in Pindorama (21°12'11"S and 48°54'34"O, at 542 m of altitude), SP. The Aw (Köppen) climate prevails in this region, with a rainy season in summer and a dry one in winter, with an average rainfall of 1,258 mm and an average temperature between 19.3 and 23.8°C (Ortolani et al., 1995). Collection composed of 165 progenies cultivated with irrigation and without tiller management, six plants/progeny totaling 990 palms, planted in 8 x 4 m spacing, totaling an area of 3.17 ha.

Area III: Located at IAC – Regional, Mococa (21°28'16"S, 47°00'23"O, at 665 m of altitude), SP. The region's climate is Aw (Köppen) with a rainy season from October to March, with 1,182 mm and average temperatures between 23 and 25°C, and a drier season, from April to September, with 283 mm and average temperature between 19 e 23°C (Ortolani et al., 1995). Collection composed of 67 progenies cultivated without irrigation and without tiller management, three plants/progeny, totaling 201 palms, planted at 8 x 4 m spacing, with a total area of 0.64 ha.

Monitoring of climatic conditions (precipitation and maximum and minimum temperatures) was carried out during the study period and water balance and evapotranspiration (ETP) were calculated (Thornthwaite, 1948). The data were collected by an automatic meteorological station (Campbell) installed close to the experimental sites.

2.2 Methodology

In each experimental area, two simultaneous experiments were carried out: characterization of the annual variation and estimation of flowering/fruiting stages.

Evaluation of annual variation: The standardization of individuals for phenological monitoring was carried out by selecting progenies with a maximum of eight tillers/plant and maximum stem height of 15m. Monthly evaluations of 173, 282 and 150 selected plants were performed for one year, totaling 12 observations in each area, from July/2013 to June/2014, July/2015 to June/2016 and July/2018 to June/2019, in areas I, II and III, respectively. The collection of phenological data took place from the record of the presence or absence, following the protocol of Bencke and Morellato (2002), of the following phenophases: flowering, characterized by the appearance of 2/3 of the floral spathe on at least one stem/palm (Figure 1a) and fruiting, characterized by the presence of bunch with unripe fruits or ripe fruits on at least one stem/palm (Figure 1b). In the data analysis, the Activity Index - AI or percentage of individuals was used: AI = 100 ($niph.tni^{-1}$), where niph is the number of individuals in the phenophase and tni is the total number of observed individuals. A non-synchronous or asynchronous phenological event was considered when <20% of individuals were in the phenophase; little synchronic or low synchrony with 20-60% of individuals in the phenophase and high synchrony with> 60% of individuals in the phenophase (Bencke and Morellato, 2002). Spearman's non-parametric correlation (rs) was calculated between the percentage of peach palms in each phenophase in the month and the climatic variables in the same month, from one and two previous months: average temperature, monthly precipitation of the year and the average of the last ten years, evapotranspiration and water balance (water deficit and water surplus). The Statgraphics 4.1 Program was used.

Figure 1. Stages of flowering and fruiting phenology of peach palms: (a) flowering phase – appearance of 2/3 of the floral spathe; (b) fruiting stage – presence of unripe or ripe fruits.

Figura 1. Etapas da fenologia de floração e frutificação de pupunheiras: (a) fase de floração – aparecimento de 2/3 da espata floral; (b) fase de frutificação – presença de frutos imaturos ou maduros.

Estimation of flowering/fruiting stages: The number of plants for this evaluation was reduced, with 30, 32 and 33 plants selected from the population of 173, 282 and 150, in each area respectively, which showed morphological characteristics favorable for better crown view and, consequently, the location of the appearance of the floral spathe (Figure 2a). Combined characteristics such as a more open clump, that is, having distant stems; height between the stems of the clump and the crown shape were considered for the selection of the plants, as they favor the visualization of the beginning of the appearance of the spathe. The definition of the phenological stages was based on Mora-Urpí (1980) and Mora-Urpí and Solís (1980): the peach palm inflorescence is monoecious; flowering is protogenic and pollination covers a period of three days. There are three pollination mechanisms: the most important is that carried out by a curculionid (*Derelomus palmarum* Champ.), the second is by wind and the third by gravity. The anthesis of all female flowers occurs at the same time in the same inflorescence, coincides with the opening of the spathe and the flowers remain fertile for 24 hours; the anthesis of the male flower occurs 24 hours after the opening of the spathe and the beginning of the female anthesis, there is the release of pollen and quickly after male flowers fall, making this event easy to visualize. The 30, 32 and 33 palms selected for areas I, II and III, respectively, were evaluated during the period from August to December of each year to identify the phases: (A) flowering: time between the appearance of the floral spathe in the palm stipe (Figure 2a), passing through the spathe opening and exposure of the inflorescence (Figure 2b) and subsequent fall of the male flowers/appearance of yellow-green fruits in the bunch (Figure 2c) and (B) fruiting: time between fall of male flowers/appearance of yellow-green fruits in the bunch (Figure 2c) and production of ripe fruits (Figure 2d).

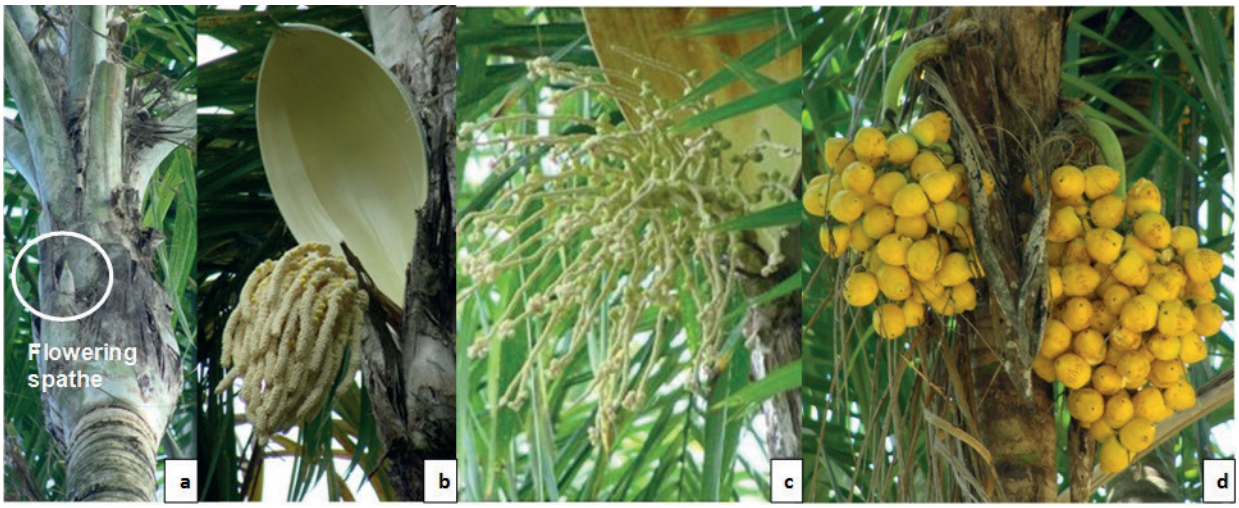

Figure 2. Phases of peach palm flowering: (a) appearance of the floral spathe; (b) spathe opening and inflorescence exposure; (c) fall of male flowers/appearance of yellow-green fruits; (d) ripe fruits in bunches (photos: Valéria A. Modolo).

Figura 2. Fases da floração de pupunheira: (a) aparecimento da espata floral; (b) abertura da espata e exposição da inflorescência; (c) queda de flores masculinas/aparecimento de frutos amarelo-esverdeados; (d) frutos maduros no cacho (fotos: Valéria A. Modolo).

After the selection and based on the results of previous experiments (Amorim et al., 2011; Silva et al., 2012; Staine et al., 2014; Souza et al., 2017), the palms were observed during the period corresponding to the beginning of flowering in the different regions. The peach palm may have several stems due to its tillering and each stem may have several spathes. The first spathe of the clump was considered and the corresponding stem was marked for monitoring. When the first spathe (Figure 2a) was sighted with the aid of a binocular, the date of its appearance was noted. After marking, the spathes were observed daily in order to check their opening for exposure of the inflorescence (Figure 2b) and the date of the fall of the male flowers/appearance of yellow-green fruits in the bunch (Figure 2c). This evaluation was carried out in the afternoon, as it was found that the spathes usually open during this period. Subsequently, the development of the fruits in these bunches was observed to note the harvest date of the ripe fruits. The means and standard deviations of each phase were estimated.

3 RESULTS AND DISCUSSION

Regarding the evaluation of the annual variation of flowering, it was observed in Figure 3a that in Pariquera-Açu, in the period of one month the percentage of plants showing spathe doubled, from 40% in October to 80% in November, reaching a maximum of 90% in December/2013 and maintaining the level of around 80% until March/2014. There was a high flowering synchrony of peach palms (above 80%), between November/2013 and March/2014. Garcia and Barbedo (2016) also observed peach palm flowering in Vale do Ribeira with the presence of floral spathes in high synchrony between the months of November and March, with more than 60% of the individuals in this phenophase. In the central Brazilian Amazon, the peach palm blooms from August to November, with the main fruiting period between December and March of the following year (Ferreira, 2005).

Figure 4a shows the characterization of the annual flowering variation observed in Pindorama, with 20% of plants showing floral spathe in July/2015, doubling each month, reaching about 40 and 80% in August and September, respectively, and reaching the maximum of almost 100% of plants blooming in October. The same growth characteristics of percentage of flowering plants were observed in the palms grown in Mococa (Figure 5a). Also in July, August and September there was an increase in the percentage of plants blooming, around 20% per month, with a maximum of approximately 90% in October and November. In both Pindorama and Mococa, the activity peak of flowering plants remained only for one month, in contrast to what occurred in Pariquera-Açu, where flowering above 80% was observed for four months (Figure 3a). Pariquera-Açu is located in Vale do Ribeira, a region characterized by a tropical rainy climate, with no defined dry season and average precipitation of the driest month exceeding 60 mm, but atypical climatic conditions was observed during the evaluation period, with rainfall between December and January/2014 below the expected average for that period (Figure 3b), which resulted in a period of water deficit between December and March, which coincided with a period of higher percentage of flowering (above 80%). In Pindorama and Mococa, after the activity peak of flowering in November, there was a more sudden drop in Pindorama, to 20% in December and more gradual in Mococa, also reaching 20% in January (Figures 4a and 5a). Both places have Aw (Köppen) climate, with small differences between precipitation and average temperatures in the winter and summer seasons. Although the evaluations took place in different years, it was observed that the volume of precipitation in January was well below average, providing periods of water deficit, alternately, during some summer months in Pindorama as well as in Mococa, in the middle of the rainy season (Figures 4b, 4c, 5b and 5c). At these locations, a second activity peak of flowering was also observed (Figures 4a and 5a), differently from what occurred in the palms grown in Pariquera-Açu (Figure 3a). Garcia and Barbedo (2016) also characterized the peach palm flowering in Vale do Ribeira as annual. In both Pindorama and Mococa it is not yet possible to state whether flowering is sub-annual, as there is a need for studies in at least two consecutive years to observe whether there is a repetition of the phenological event. In Pindorama, starting in March, there was an increase of around 25% per month of plants showing spathe, reaching almost 80% of the plants blooming in June (Figure 4a). This period coincided with consecutive months of water deficit (Figure 4c). The second activity peak of flowering in Mococa was not gradual like the first one (Figure 5c) and in two months, from February to April, the percentage of plants blooming increased from 20% to over 80%, also coinciding with a period of water deficit (Figure 5c).

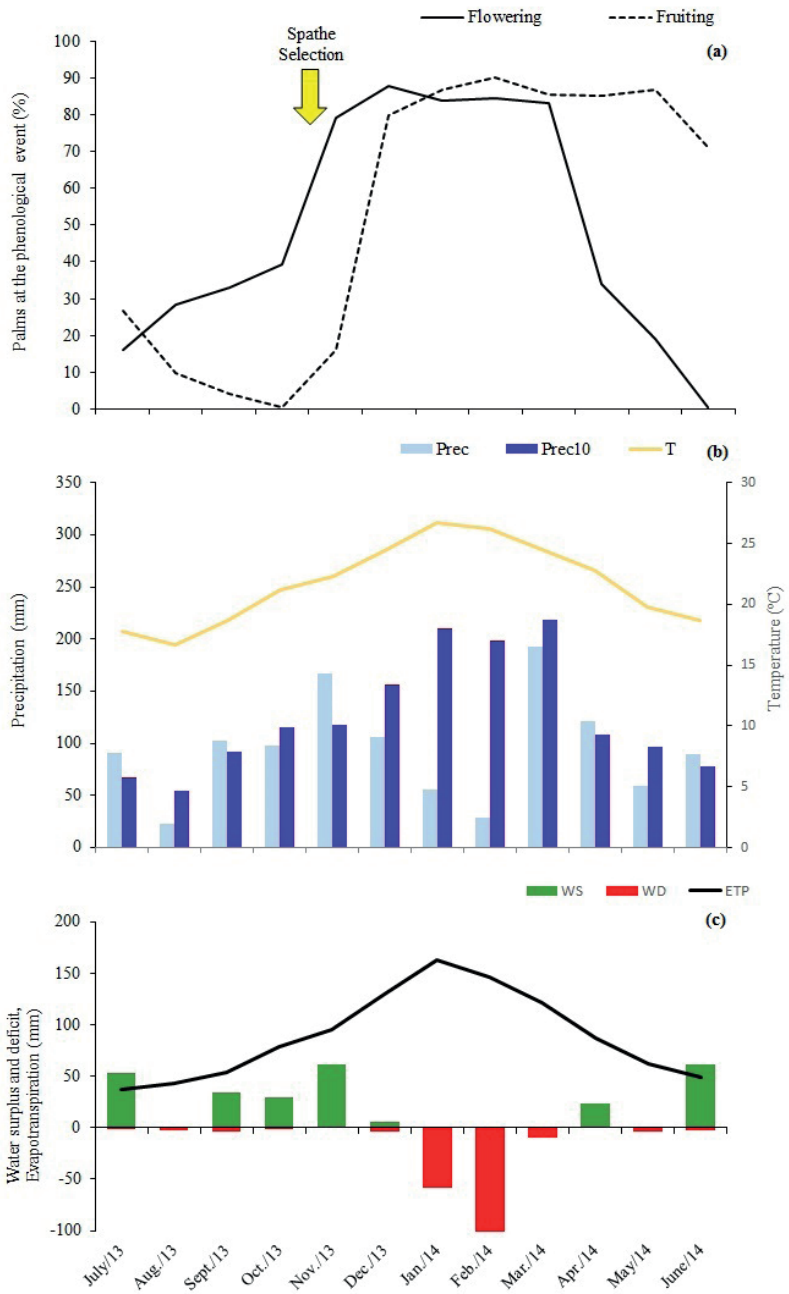

Figure 3. Reproductive phenology of *Bactris gasipaes* in Area I. (a) Percentage of palms showing the phenophases of flowering (appearance of 2/3 of the floral spathe) and fruiting (presence of bunch with young and/or ripe fruits); (b) Average precipitation over the last ten years (Prec10), monthly precipitation of the year (Prec) and monthly average temperature (T); (c) Evapotranspiration (ETP), Water Surplus (WS) and Water Deficit (WD). Pariquera-Açu, SP (July/2013 to June/2014). Source (b) and (c): IAC Meteorological Stations Network, Campinas, SP.

Figura 3. Fenologia reprodutiva de *Bactris gasipaes* na Área I. (a) Porcentagem de palmeiras apresentando as fenofases de floração (aparecimento de 2/3 da espata floral) e frutificação (presença de cacho com frutos imaturos e/ou maduros); (b) Precipitação média dos últimos dez anos (Prec10), Precipitação mensal do ano (Prec) e Temperatura média mensal (T); (c) Evapotranspiração (ETP); Excedente Hídrico (WS) e Déficit Hídrico (WD). Pariquera-Açu, SP (julho/2013 a junho/2014). Fonte (b) e (c): Rede de Estações Meteorológicas do IAC, Campinas, SP.

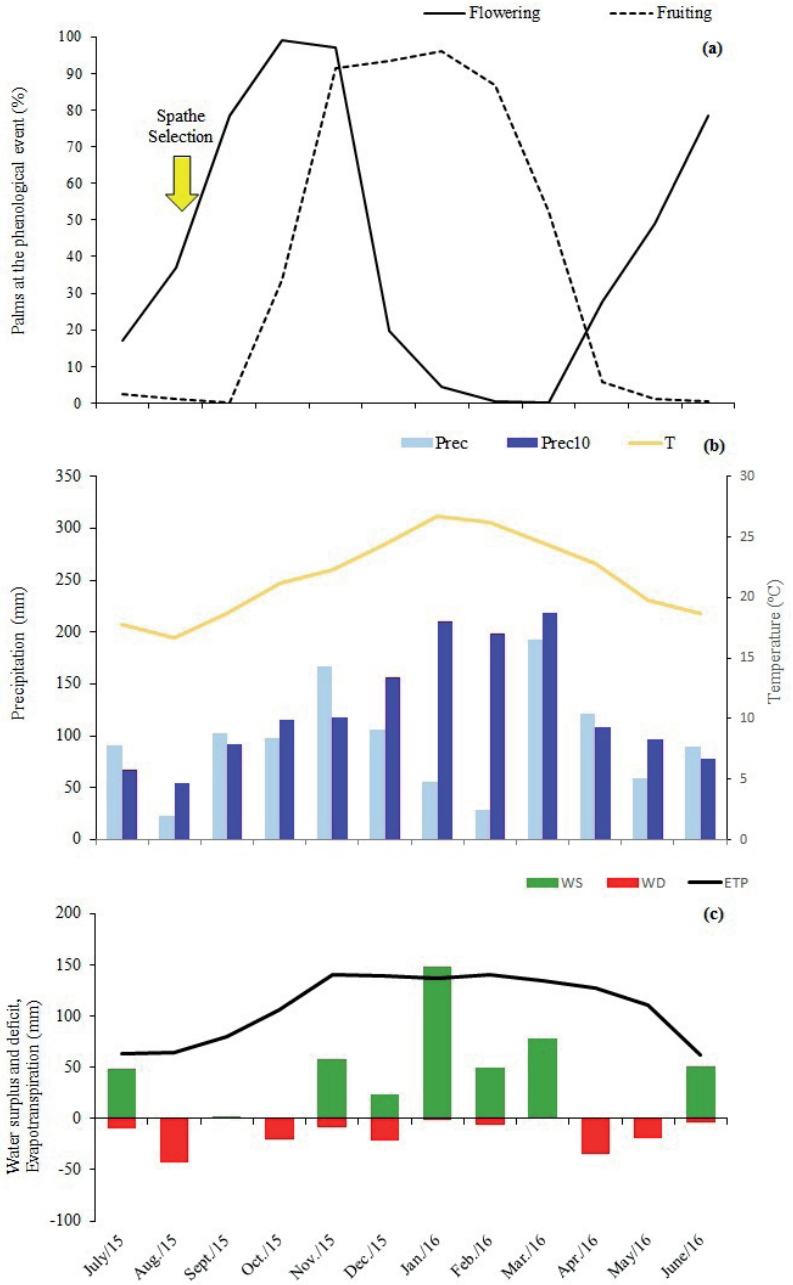

Figure 4. Reproductive phenology of *Bactris gasipaes* in in Area II. (a) Percentage of palms showing the phenophases of flowering (appearance of 2/3 of the floral spathe) and fruiting (presence of bunch with young and/or ripe fruits); (b) Average precipitation over the last ten years (Prec10), monthly precipitation of the year (Prec) and monthly average temperature (T); (c) Evapotranspiration (ETP), Water Surplus (WS) and Water Deficit (WD). Pindorama, SP (July/2015 to June/2016). Source (b) and (c): IAC Meteorological Stations Network, Campinas, SP.

Figura 4. Fenologia reprodutiva de *Bactris gasipaes* na Área II. (a) Porcentagem de palmeiras apresentando as fenofases de floração (aparecimento de 2/3 da espata floral) e frutificação (presença de cacho com frutos novos e/ou frutos maduros); (b) Precipitação média dos últimos dez anos (Prec10), Precipitação mensal do ano (Prec) e Temperatura média mensal (T); (c) Evapotranspiração (ETP); Excedente Hídrico (WS) e Déficit Hídrico (WD). Pindorama, SP (julho/2015 a junho/2016). Fonte (b) e (c): Rede de Estações Meteorológicas do IAC, Campinas, SP.

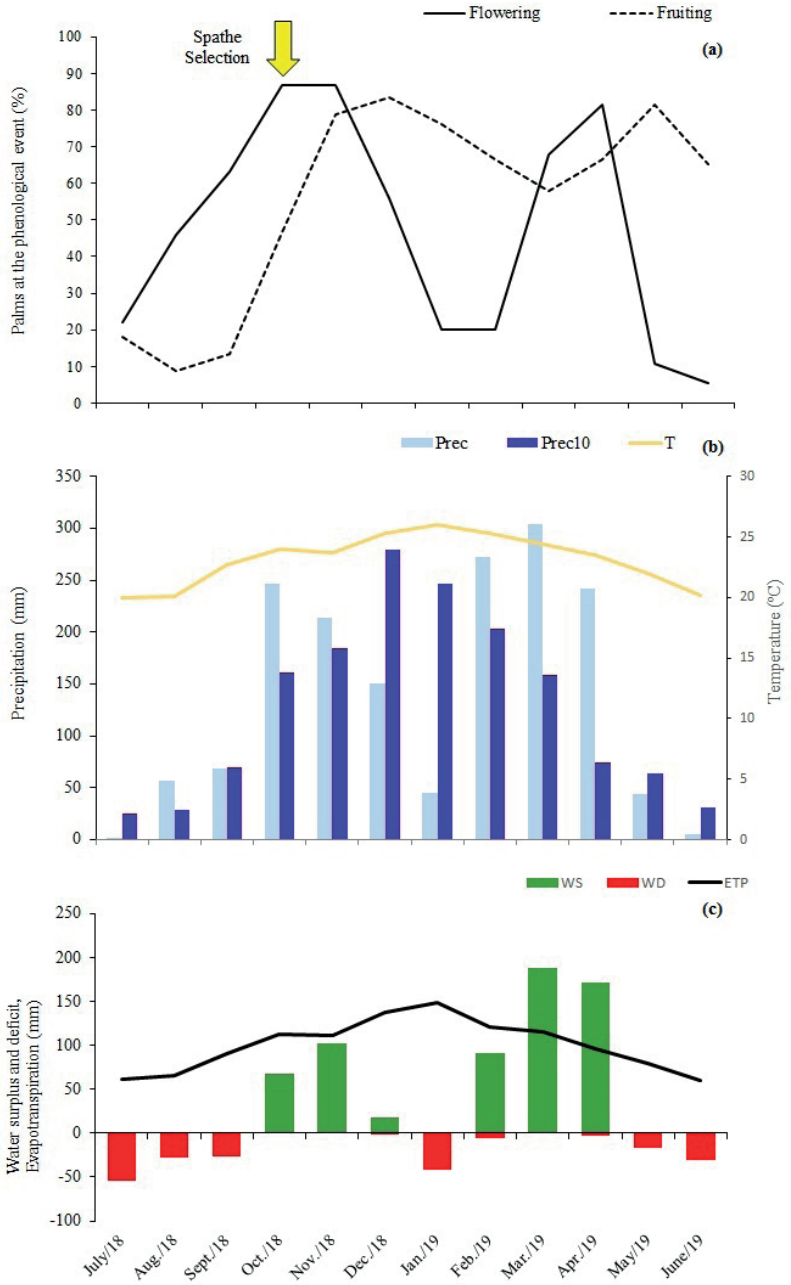

Figure 5. Reproductive phenology of *Bactris gasipaes* in Area III. (a) Percentage of palms showing the phenophases of flowering (appearance of 2/3 of the floral spathe) and fruiting (presence of bunch with young and/or ripe fruits); (b) Average precipitation over the last ten years (Prec10), monthly precipitation of the year (Prec) and monthly average temperature (T); (c) Evapotranspiration (ETP), Water Surplus (WS) and Water Deficit (WD). Mococa, SP (July/2018 to June/2019). Source (b) and (c): IAC Meteorological Stations Network, Campinas, SP.

Figura 5. Fenologia reprodutiva de *Bactris gasipaes* na Área III. (a) Porcentagem de palmeiras apresentando as fenofases de floração (aparecimento de 2/3 da espata floral) e frutificação (presença de cacho com frutos novos e/ou frutos maduros); (b) Precipitação média dos últimos dez anos (Prec10), Precipitação mensal do ano (Prec) e Temperatura média mensal (T); (c) Evapotranspiração (ETP); Excedente Hídrico (WS) e Déficit Hídrico (WD). Mococa, SP (julho/2018 a junho/2019). Fonte (b) e (c): Rede de Estações Meteorológicas do IAC, Campinas, SP.

Correlating flowering with climatological elements, it can be seen in Table 1 that in Pariquera-Açu there was no correlation between flowering and precipitation, water deficit and water surplus, but there was a very high Spearman correlation (rs = 0.916) between appearance of spathes (flowering) and evapotranspiration in the same month and moderate in the previous month (rs = 0.636) and also with the average temperature (rs = 0.839) in the same month. The potential evapotranspiration (ETP) is indicative of the evapotranspiration demand of the atmosphere of a place, in a period, defined by the combined effect of the net radiation, temperature, relative humidity and wind speed (Pereira et al., 2002). The high evapotranspiration associated with a condition of water deficit in the soil (Figure 3c) can cause a stress condition in the plant favorable to the appearance of spathe. In the regions of the São Paulo plateau, there was a positive correlation between precipitation and flowering in Mococa (rs = 0.635) where there was no irrigation, but in Pindorama, whose area was irrigated, there was no correlation between the climatic elements, only an inversely proportional correlation with the water surplus (Table 1). According to Rocha et al. (2015) in *Copernicia prunifera* (Arecaceae), the appearance of flower buds significantly correlated with all analyzed climatic variables, with a higher emission of flower buds with the increase in temperature, precipitation and relative air humidity. In peach palm, Mora-Urpí and Solís (1980) studying pollination in Costa Rica in two ecologically different regions reported that flowering in the Pacific hillside region (9º22', 690 m, average temperature of 25.5ºC, average rainfall of 1,942 mm and with defined dry season) coincides with the dry season, whereas in the region of the Atlantic hillside (10º13', 280 m, average temperature of 25.1ºC, precipitation of 4,392 mm) occurs in the rainy season. Garcia and Barbedo (2016) found that the activity peaks of flowering in Vale do Ribeira, SP, occurred in months with high precipitation and temperature. According to Mora-Urpí et al. (1984) the time for fruit production in peach palm is determined by precipitation and periods of drought. The regions studied in São Paulo seem to have been influenced by periods of drought (water deficit) at the beginning and duration of the flowering period. Simultaneous studies in different locations, with distinct climatic characteristics, can better elucidate the relationship between water deficit and flowering period in peach palm.

Regarding fruiting, the presence of plants with fruit bunches, unripe or ripe, was observed in almost all months of evaluation (Figures 3a, 4a and 5a). In Pariquera-Açu from December/2013, there were more than 70% of stems with fruits until the end of the evaluation (June/2014) (Figure 3a). In Pindorama, the activity peak of fruiting was concentrated between November/2015 and February/2016 (Figure 4a), with more than 85% of the plants with fruit bunches. Yet in Mococa (Figure 5a), a lower percentage of fruiting plants was observed (maximum 83% in December/2018), but the distribution over the months was similar to Pariquera-Açu, that is, above 60% of plants with fruits for seven months of the observed period. This may have occurred due to the proximity of the two activity peaks of flowering observed in Mococa, in addition to the fact that flowering was gradual over the months of observation (Figure 5a). According to Ferreira (2005), in the region of Manaus (AM) the harvest of the first ripe bunches begins in December and extends until March. It was also noted by the author that, in favorable edaphoclimatic conditions, a period of less flowering may occur during May-June with fruiting in August-September, especially after a year of little fruiting. According to Mora-Urpí et al. (1984) in Costa Rica, the main harvest is between May and June in the South Pacific region, from June to August in the central Pacific region and from August to November in the Caribbean and northern Costa Rica regions, depending on the rainfall regime these periods can be more or less extended.

Table 1. Spearman's correlation coefficient (rs) between percentage of peach palms in each phenophase (flowering and fruiting) per month and climatic variables in the same month (0), one (1) and two (2) previous months: average temperature (T), monthly precipitation of the year (Prec), Evapotranspiration (ETP), Water Deficit (WD) and Water Surplus (WS), between July and June 2013/2014 for Pariquera-Açu, 2015/2016 for Pindorama and 2018/2019 for Mococa; ns, not significant correlation (* $p \leq 0.05$; ** $p \leq 0.01$). Instituto Agronômico (IAC), Campinas, SP.

Tabela 1. Coeficiente de correlação de Spearman (rs) entre porcentagem de pupunheiras em cada fenofase (floração e frutificação) por mês e as variáveis climáticas no mesmo mês (0), de um (1) e de dois (2) meses anteriores: Temperatura média (T), Precipitação mensal do ano (Prec), Evapotranspiração (ETP), Déficit Hídrico (WD) e Excedente Hídrico (WS), entre julho e junho de 2013/2014 para Pariquera-Açu, de 2015/2016 para Pindorama e de 2018/2019 para Mococa; ns, correlação não significativa (*$p \leq 0,05$; **$p \leq 0,01$). Instituto Agronômico (IAC), Campinas, SP.

Month		Pariquera-Açu		Pindorama		Mococa	
		Flowering	Fruiting	Flowering	Fruiting	Flowering	Fruiting
T	0	0.839**	0.683*	ns	0.743*	ns	ns
	1	ns	0.900**	ns	0.743*	ns	0.631*
	2	ns	0.837**	ns	ns	ns	ns
Prec	0	ns	ns	ns	ns	0.635*	ns
	1	ns	ns	ns	ns	ns	0.595*
	2	ns	ns	ns	ns	ns	0.820**
ETP	0	0.916**	0.599*	ns	0.823**	ns	ns
	1	0.636*	0.886**	ns	0.620*	ns	0.606*
	2	ns	0.872**	ns	ns	ns	ns
WD	0	ns	ns	ns	ns	-0.732*	ns
	1	ns	ns	ns	ns	ns	-0.780**
	2	ns	ns	ns	ns	ns	-0.833**
WS	0	ns	ns	ns	ns	0.657*	ns
	1	ns	ns	-0.603*	ns	ns	0.705*
	2	ns	ns	ns	ns	-0.659*	0.632*

In the three locations, there was a correlation between fruiting and average temperature and evapotranspiration, mainly with data from the previous month (Table 1). In Mococa, there was also positive correlations with precipitation and water surplus and a negative correlation with water deficit, between fruiting and previous months data, indicating that the higher the temperature and the precipitation the greater the presence of fruits. Similar correlations were observed by Chagas et al. (2019) in works in a natural oil palm population, in Macaíba (RN), reporting positive correlations between fruiting and average temperature, humidity and precipitation.

Regarding the flowering and fruiting stages, there was a loss of plants during the evaluation due to stems falling caused by storms or spathe falling. In Pariquera-Açu, 93% of the marked spathes opened in inflorescence, but there was no harvest of ripe fruits due to the intense attack by birds that dropped the fruits, making it impossible to count the duration of fruiting. In Pindorama, there was a fall of 9 marked stems due to a windstorm, 3 before the opening of the spathes and 6 during fruiting. Of the total evaluated, 93% of the marked spathes became inflorescence and 97% formed bunches with ripe fruits. In Mococa, 94% of the marked spathes became inflorescence and only 44% of them formed bunches with ripe fruits. The peach palm, especially when grown on the São Paulo plateau, suffers a lot from unfavorable climatic conditions and may not even have the reproductive phase. In this work, there was a concern in selecting plants that had already fruited in previous years, but for future experiments, the number of plants observed should also be increased. Especially in the Collection of palms grown in Mococa, the lack of irrigation may have been decisive in the low percentage of fruiting. According to Modolo et al. (2018) regions of the São Paulo plateau, such as Pindorama and Mococa, are more suitable for the production of peach palm seeds mainly because the average percentage of flowering plants is comparatively higher than in the Vale do Ribeira and the lower appearance of parthenocarpic fruits. However, the need for irrigation in this region must be emphasized for fruit and seed production to be effective.

The average time for flowering was 41 days in Pariquera-Açu, 50 days in Pindorama and 43 days in Mococa (Figure 6). However, observing Table 2, which shows the total number of plants marked per decade and the total number of plants that effectively completed the flowering phase, it was found that in Pindorama the average number of days for flowering, considering only the number of plants observed per ten-day period, was higher in those that were marked at the beginning of the flowering phase than those marked at the end. In Pindorama, 46% of the plants were marked between 08/21 and 09/10 and in these plants flowering lasted more than 60 days. In the next three ten-day periods (from 09/11 to 10/10) the average days for flowering was 38, with the flowering time of the plant marked in the last ten days (late October) decreasing to 20 days. In Mococa and Pariquera-Açu the number of days for flowering, regardless of the period of marking the spathes, remained constant, except for the last spathe marked in Mococa (11/20), which, as in Pindorama, took only 21 days to open in inflorescence. Even considering previous works to determine the beginning of marking the spathes, there was a very variable period at different locations between the appearance and opening of the spathes. In future experiments, a larger number of evaluated plants should be considered, a longer period of plant marking and scheduling of plants evaluated during this period.

The average time for fruiting was 116 and 78 days for peach palms grown in Pindorama and Mococa, respectively (Figure 6). According to Mora-Urpí et al. (1984) the time for fruit formation, from flowering to the beginning of ripening, is approximately 115 days. In the Central Amazon this period is, on average, 110 days (Ferreira, 2005).

In Mococa, this reduced fruiting time (78 ± 19), below the average of Pindorama and other sites reported in the literature, may be due to the low water availability, which may have anticipated the maturation process. The peach palm collection has no irrigation and the beginning of fruiting occurred between December and January, a period with precipitation well below the average (Figure 5b), causing a period of water deficit (Figure 5c) at the beginning of fruiting, the most critical period in terms of fruit formation.

Table 2. Number and percentage of plants evaluated in each ten-day period between August and November 2013 for Pariquera-Açu, 2015 for Pindorama and 2018 for Mococa and number of days for flowering. Instituto Agronômico (IAC), Campinas, SP.

Tabela 2. Número e porcentagem de plantas avaliadas em cada decêndio entre agosto e novembro de 2013 para Pariquera-Açu, de 2015 para Pindorama e de 2018 para Mococa e número de dias para floração. Instituto Agronômico (IAC), Campinas, SP.

Ten-day period	August	September			October			November		Total plants
	21 - 31	01 - 10	11 - 20	21 - 30	01 - 10	11 - 20	21 - 30	1 - 10	11 - 20	
Pariquera-Açu (2013)										
Number of plants					3	15	6	3	1	28
Percentage of plants (%)					10.7	53.6	21.4	10.7	3.6	
Number of days to flowering					45.3	40.0	38.0	38.7	45.0	
Pindorama (2015)										
Number of plants	1	11	1	7	5	1				26
Percentage of plants (%)	3.8	42.3	3.8	26.9	19.2	3.8				
Number of days to flowering	66.0	61.2	39.0	39.1	35.2	20				
Mococa (2018)										
Number of plants						26	2	2	1	31
Percentage of plants (%)						83.9	6.4	6.4	3.2	
Number of days to flowering						43.0	45.5	40.0	21.0	

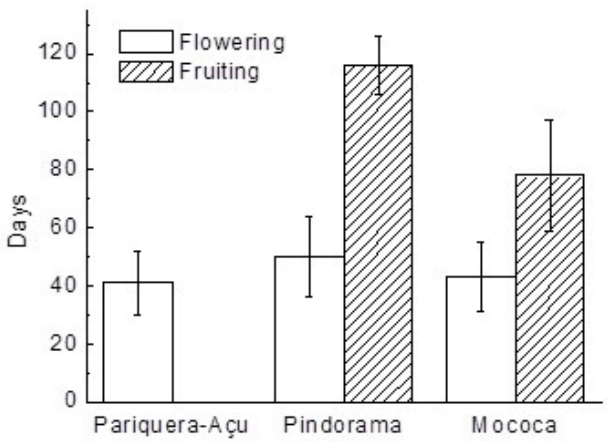

Figure 6. Average number of days (± standard deviation) for flowering and fruiting of peach palms cultivated in Pariquera-Açu, Pindorama and Mococa, SP. IAC, Campinas, SP.

Figura 6. Valor médio do número de dias (± desvio padrão) para floração e frutificação de pupunheiras cultivadas em Pariquera-Açu, Pindorama e Mococa, SP. IAC, Campinas, SP.

4 CONCLUSIONS

The flowering time of peach palm depends on the location where the palm is grown, being influenced by the average temperature and evapotranspiration in Pariquera-Açu and by the rainfall in Mococa. The predominant climatic elements in fruiting in the three locations are evapotranspiration and average temperature in the month preceding the phenological event and in Mococa it is also influenced by precipitation.

The average time for peach palm flowering is 41, 50 and 43 days for palms grown in Pariquera-Açu, Pindorama and Mococa, respectively. The fruiting in Pindorama lasts 116 days, with a total cycle of 166 days.

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